FINAL SOLOMON CREEK WATERSHED TMDL

Luzerne County

Prepared for:

Pennsylvania Department of Environmental Protection

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TMDL[1]
Solomon Creek Watershed
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INTRODUCTION

This report presents the Total Maximum Daily Load (TMDL) developed for stream segments in the Solomon Creek Watershed (Attachment A). This was done to address impairments noted on the 1996, 1998, 2002, and 2004 Pennsylvania Section 303(d) lists required under the Clean Water Act and covers three segments on this list (Table 1). High levels of suspended solids and depressed pH caused these impairments. All impairments resulted from acid drainage from abandoned coal mines. The TMDL addresses the three primary metals (iron, manganese, aluminum) associated with acid mine drainage (AMD) and pH.

Table 1. Solomon Creek Segments Addressed

State Water Plan (SWP) Subbasin: 05-B Susquehanna River								
Year	Miles	Segment ID	DEP Stream Code	Stream Name	Designated Use	Data Source	Source	EPA 305(b) Cause Code
1996	2.4	Not placed on GIS	28352	Solomon Creek	CWF	305(b) Report	RE	pH, Suspended Solids
1998	2.4	Not placed on GIS	28352	Solomon Creek	CWF	305(b) Report	AMD	pH, Suspended Solids
2002	4.8	Not placed on GIS	28352	Solomon Creek	CWF	305(b) Report	AMD	pH, Suspended Solids
2004	4.0	20010718-0900_CJD	28352	Solomon Creek	CWF	Surface Water Assessment Program	AMD	Siltation, Metals
2004	1.9	20010718-0900_CJD	28353	Spring Run	CWF	Surface Water Assessment Program	AMD	Metals, Siltation
2004	2.6	20010718-1120-CJD	63991	Sugar Notch Run	CWF	Surface Water Assessment Program	AMD	Flow Alterations

See Attachment B, Excerpts Justifying Changes Between the 1996, 1998, 2002, and 2004 Section 303(d) lists.
The use designations for the stream segments in this TMDL can be found in PA Title 25 Chapter 93.

CWF = Cold Water Fishes
RE = Resource Extraction
AMD = Abandoned Mine Drainage

[1] Pennsylvania's 1996, 1998, 2002, and 2004 Section 303(d) lists were approved by the Environmental Protection Agency (USEPA). The 1996 Section 303(d) list provides the basis for measuring progress under the 1996 lawsuit settlement of *American Littoral Society and Public Interest Group of Pennsylvania v. EPA.*

LOCATION

The Solomon Creek Watershed is approximately 18.2 square miles in area. It is located south of Wilkes-Barre, Luzerne County, Pennsylvania. Solomon Creek flows six miles north from its headwaters near Solomon Gap, Fairview Township, Luzerne County, until Lee Park, where it flows west to its confluence with the Susquehanna River. The headwaters of Solomon Creek are located in a forested area upstream of coal areas. The northern portion of the watershed lies in south Wilkes-Barre. Solomon Creek Watershed can be accessed traveling on I-81 to exit 165B (State Route 309). Interstate 81 and State Route 309 both bisect the watershed.

SEGMENTS ADDRESSED IN THIS TMDL

The Solomon Creek Watershed is affected by pollution from AMD. This pollution has caused high levels of suspended solids and low pH in the mainstem of Solomon Creek and two small tributaries, Spring Run and Sugar Notch Run. The mainstem of Solomon Creek is impaired from Spring Run to its confluence with the Susquehanna River. Spring Run and Sugar Notch Run are impaired for their entire lengths.

CLEAN WATER ACT REQUIREMENTS

Section 303(d) of the 1972 Clean Water Act requires states, territories, and authorized tribes to establish water quality standards. The water quality standards identify the uses for each waterbody and the scientific criteria needed to support that use. Uses can include designations for drinking water supply, contact recreation (swimming), and aquatic life support. Minimum goals set by the Clean Water Act require that all waters be "fishable" and "swimmable."

Additionally, the federal Clean Water Act and the U.S. Environmental Protection Agency's (USEPA) implementing regulations (40 CFR Part 130) require:

- States to develop lists of impaired waters for which current pollution controls are not stringent enough to meet water quality standards (the list is used to determine which streams need TMDLs);

- States to establish priority rankings for waters on the lists based on severity of pollution and the designated use of the waterbody; states must also identify those waters for which TMDLs will be developed and a schedule for development;

- States to submit the list of waters to USEPA every two years (April 1 of the even numbered years);

- States to develop TMDLs, specifying a pollutant budget that meets state water quality standards and allocate pollutant loads among pollution sources in a watershed, e.g., point and nonpoint sources; and

- USEPA to approve or disapprove state lists and TMDLs within 30 days of final submission.

Despite these requirements, states, territories, authorized tribes, and USEPA have not developed many TMDLs since 1972. Beginning in 1986, organizations in many states filed lawsuits against the USEPA for failing to meet the TMDL requirements contained in the federal Clean Water Act and its implementing regulations. While USEPA has entered into consent agreements with the plaintiffs in several states, many lawsuits still are pending across the country.

In the cases that have been settled to date, the consent agreements require USEPA to backstop TMDL development, track TMDL development, review state monitoring programs, and fund studies on issues of concern (e.g., AMD, implementation of nonpoint source Best Management Practices, etc.). These TMDLs were developed in partial fulfillment of the 1996 lawsuit settlement of *American Littoral Society and Public Interest Group of Pennsylvania v. EPA*.

SECTION 303(D) LISTING PROCESS

Prior to developing TMDLs for specific waterbodies, there must be sufficient data available to assess which streams are impaired and should be on the Section 303(d) list. With guidance from the USEPA, the states have developed methods for assessing the waters within their respective jurisdictions.

The primary method adopted by the Pennsylvania Department of Environmental Protection (PADEP) for evaluating waters changed between the publication of the 1996 and 1998 Section 303(d) lists. Prior to 1998, data used to list streams were in a variety of formats, collected under differing protocols. Information also was gathered through the Section 305(b)[2] reporting process. PADEP is now using the Unassessed Waters Protocol (UWP), a modification of the USEPA Rapid Bioassessment Protocol II (RPB-II), as the primary mechanism to assess Pennsylvania's waters. The UWP provides a more consistent approach to assessing Pennsylvania's streams.

The assessment method requires selecting representative stream segments based on factors such as surrounding land uses, stream characteristics, surface geology, and point source discharge locations. The biologist selects as many sites as necessary to establish an accurate assessment for a stream segment; the length of the stream segment can vary between sites. All the biological surveys include kick-screen sampling of benthic macroinvertebrates, habitat surveys, and measurements of pH, temperature, conductivity, dissolved oxygen, and alkalinity. Benthic macroinvertebrates are identified to the family level in the field.

After the survey is completed, the biologist determines the status of the stream segment. The decision is based on the performance of the segment using a series of biological metrics. If the stream is determined to be impaired, the source and cause of the impairment is documented. An impaired stream must be listed on the state's Section 303(d) list with the documented source and

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[2] Section 305(b) of the Clean Water Act requires a biannual description of the water quality of the waters of the state.

cause. A TMDL must be developed for the stream segment. A TMDL is for only one pollutant. If a stream segment is impaired by two pollutants, two TMDLs must be developed for that stream segment. In order for the process to be more effective, adjoining stream segments with the same source and cause listing are addressed collectively, and on a watershed basis.

BASIC STEPS FOR DETERMINING A TMDL

Although all watersheds must be handled on a case-by-case basis when developing TMDLs, there are basic processes or steps that apply to all cases. They include:

1. Collect and summarize pre-existing data (watershed characterization, inventory contaminant sources, determination of pollutant loads, etc.);
2. Calculate TMDL for the waterbody using USEPA approved methods and computer models;
3. Allocate pollutant loads to various sources;
4. Determine critical and seasonal conditions;
5. Submit draft report for public review and comments; and
6. Obtain USEPA approval of the TMDL.

This document will present the information used to develop the Solomon Creek Watershed TMDL.

WATERSHED BACKGROUND

The Solomon Creek Watershed lies within the Anthracite Valley Section of the Ridge and Valley Province. There is a vertical drop in the watershed of 1,590 feet from its headwaters to its mouth. The average annual precipitation is 42 inches. The region is characterized by warm summers and long, cold winters. Temperatures change frequently and sometimes rapidly.

The watershed is dominated primarily by developed and forested land uses. Forested land makes up 60 percent of the watershed and 26 percent of the area is considered developed. The majority of the developed land is located in the northern portion of the watershed, which encompasses part of Wilkes-Barre. Disturbed land (abandoned coal mines, quarries, etc.) comprise of almost seven percent of the watershed.

Solomon Creek Watershed is composed primarily of interbedded sedimentary rock, which accounts for 77.4 percent of the watershed. Sandstone comprises the remaining 22.6 percent of the area. The predominant soil associations in the watershed are the Lackawanna-Arnot-Morris and Udorthents-Urban Land-Vlousia series accounting for 45 percent and 39.3 percent, respectively. The remaining portion of the watershed is comprised of the Wellsboro-Oquaga-Morris and Chenango-Pope-Holly soil associations (9.3 percent and 6.4 percent, respectively). Currently, the entire basin of Solomon Creek is listed as a CWF by Pennsylvania Code Title 25.

Historical data shows that deep mining began in this area in the early nineteenth century and continued until the 1970s. Currently, there is one remining permit (surface mining) in the watershed (Permit #40990201CB); however, it does not discharge and, thus, it does not require a waste load allocation. Pumping water from the mine pools below Solomon Creek was discontinued in 1967. Once pumping stopped, the mine pool levels began to rise and after Hurricane Agnes in 1972, basements began to flood in area homes from significant increases in mine pool levels. In order to control the flooding, three boreholes (known as the South Wilkes-Barre Boreholes) and the Buttonwood Tunnel Outlet were drilled next to Solomon Creek (GEO-Technical, 1975).

Sugar Notch Run and Spring Run are small tributaries to Solomon Creek. Both of these streams are severely impacted by AMD and lose water to underground mine pools. Spring Run loses most of its flow before reaching Solomon Creek. Sugar Notch Run loses 75 percent of it flow when it reaches mined areas (GEO-Technical, 1975).

There have been several studies within the watershed to assess the biological community and water quality (GEO-Technical, 1975, Bruns and others, 2001, and Wood, 1996). The Eastern PA Coalition for Abandoned Mine Reclamation (EPCAMR) conducted sampling of benthic macroinvertebrates and water chemistry in the Solomon Creek Watershed in 2003. The sampling performed at the boreholes in Solomon Creek found no macroinvertebrates present and the stream index is rated as poor (Hughes and others, 2003). The absence of any fish species is documented in the Scarlift Report. Based its relative size, the Solomon Creek watershed has the highest iron loading of all streams in the Upper Susquehanna River-Lackawanna River Watershed (Bruns and others, 2001). Upstream of all coal activity the creek is unpolluted (GEO-Technical, 1975).

TMDLS TO ADDRESS AMD IMPAIRMENT

AMD METHODOLOGY

A two-step approach is used for the TMDL analysis of AMD impaired stream segments. The first step uses a statistical method for determining the allowable instream concentration at the point of interest necessary to meet water quality standards. This is done at each point of interest (sample point) in the watershed. The second step is a mass balance of the loads as they pass through the watershed. Loads at these points will be computed based on average annual flow.

The statistical analysis described below can be applied to situations where all of the pollutant loading is from nonpoint sources, as well as those where there are both point and nonpoint sources. The following defines what are considered point sources and nonpoint sources for the purposes of our evaluation; point sources are defined as permitted discharges or a discharge that has a responsible party, nonpoint sources are then any pollution sources that are not point sources. For situations where all of the impact is due to nonpoint sources, the equations shown below are applied using data for a point in the stream. The load allocation made at that point will be for all of the watershed area that is above that point. For situations where there are point source impacts alone, or in combination with nonpoint sources, the evaluation will use the point source data and perform a mass balance with the receiving water to determine the impact of the point source.

Allowable loads are determined for each point of interest using Monte Carlo simulation. Monte Carlo simulation is an analytical method meant to imitate real-life systems, especially when other analyses are too mathematically complex or too difficult to reproduce. Monte Carlo simulation calculates multiple scenarios of a model by repeatedly sampling values from the probability distribution of the uncertain variables and using those values to populate a larger data set. Allocations were applied uniformly for the watershed area specified for each allocation point. For each source and pollutant, it was assumed that the observed data were log-normally distributed. Each pollutant source was evaluated separately using @Risk[3] by performing 5,000 iterations to determine the required percent reduction so that the water quality criteria, as defined in the *Pennsylvania Code, Title 25 Environmental Protection, Department of Environmental Protection, Chapter 93, Water Quality Standards,* will be met instream at least 99 percent of the time. For each iteration, the required percent reduction is:

PR = maximum {0, (1-Cc/Cd)} where (1)

PR = required percent reduction for the current iteration

Cc = criterion in mg/l

Cd = randomly generated pollutant source concentration in mg/l based on the observed data

Cd = RiskLognorm(Mean, Standard Deviation) where (1a)
Mean = average observed concentration

Standard Deviation = standard deviation of observed data

The overall percent reduction required is the 99th percentile value of the probability distribution generated by the 5,000 iterations, so that the allowable long-term average (LTA) concentration is:

LTA = Mean * (1 – PR99) where (2)

LTA = allowable LTA source concentration in mg/l

Once the allowable concentration and load for each pollutant is determined, mass-balance accounting is performed starting at the top of the watershed and working down in sequence. This mass-balance or load tracking is explained below.

Load tracking through the watershed utilizes the change in measured loads from sample location to sample location, as well as the allowable load that was determined at each point using the @Risk program.

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[3] @Risk – Risk Analysis and Simulation Add-in for Microsoft Excel, Palisade Corporation, Newfield, NY, 1990-1997.

There are two basic rules that are applied in load tracking; rule one is that if the sum of the measured loads that directly affect the downstream sample point is less than the measured load at the downstream sample point it is indicative that there is an increase in load between the points being evaluated, and this amount (the difference between the sum of the upstream and downstream loads) shall be added to the allowable load(s) coming from the upstream points to give a total load that is coming into the downstream point from all sources. The second rule is that if the sum of the measured loads from the upstream points is greater than the measured load at the downstream point this is indicative that there is a loss of instream load between the evaluation points, and the ratio of the decrease shall be applied to the load that is being tracked (allowable load(s)) from the upstream point.

Tracking loads through the watershed gives the best picture of how the pollutants are affecting the watershed based on the information that is available. The analysis is done to insure that water quality standards will be met at all points in the stream. The TMDL must be designed to meet standards at all points in the stream, and in completing the analysis, reductions that must be made to upstream points are considered to be accomplished when evaluating points that are lower in the watershed. Another key point is that the loads are being computed based on average annual flow and should not be taken out of the context for which they are intended, which is to depict how the pollutants affect the watershed and where the sources and sinks are located spatially in the watershed.

For pH TMDLs, acidity is compared to alkalinity as described in the following section. Each sample point used in the analysis of pH by this method must have measurements for total alkalinity and total acidity. Net alkalinity is alkalinity minus acidity, both in units of milligrams per liter (mg/l) $CaCO_3$. Statistical procedures are applied, using the average value for total alkalinity at that point as the target to specify a reduction in the acid concentration. By maintaining a net alkaline stream, the pH value will be in the range between six and eight. This method negates the need to specifically compute the pH value, which for streams affected by low pH from AMD may not a true reflection of acidity. This method assures that Pennsylvania's standard for pH is met when the acid concentration reduction is met.

Information for the TMDL analysis performed using the methodology described above is contained in the "TMDLs by Segment" section of this report.

TMDL ENDPOINTS

One of the major components of a TMDL is the establishment of an instream numeric endpoint, which is used to evaluate the attainment of acceptable water quality. An instream numeric endpoint, therefore, represents the water quality goal that is to be achieved by implementing the load reductions specified in the TMDL. The endpoint allows for comparison between observed instream conditions and conditions that are expected to restore designated uses. The endpoint is based on either the narrative or numeric criteria available in water quality standards.

Because of the nature of the pollution sources in the watershed, the TMDLs component makeup will be load allocations that are specified above a point in the stream segment. All allocations will be specified as long-term average daily concentrations. These long-term average daily concentrations are expected to meet water quality criteria 99 percent of the time. Pennsylvania Title 25 Chapter 96.3(c) specifies that a minimum 99 percent level of protection is required. All metals criteria evaluated in this TMDL are specified as total recoverable. Table 2 shows the water quality criteria for the selected parameters.

Table 2. Applicable Water Quality Criteria

Parameter	*Criterion Value (mg/l)*	*Total Recoverable/Dissolved*
Aluminum (Al)	0.75	Total Recoverable
Iron (Fe)	1.50 0.3	30-day average; Total Recoverable Dissolved
Manganese (Mn)	1.00	Total Recoverable
pH *	6.0-9.0	N/A

*The pH values shown will be used when applicable. In the case of freestone streams with little or no buffering capacity, the TMDL endpoint for pH will be the natural background water quality. These values are typically as low as 5.4 (Pennsylvania Fish and Boat Commission).

TMDL ELEMENTS (WLA, LA, MOS)

A TMDL equation consists of a wasteload allocation (WLA), load allocation (LA) and a margin of safety (MOS). The WLA is the portion of the load assigned to point sources. The LA is the portion of the load assigned to nonpoint sources. The MOS is applied to account for uncertainties in the computational process. The MOS may be expressed implicitly (documenting conservative processes in the computations) or explicitly (setting aside a portion of the allowable load).

TMDL ALLOCATIONS SUMMARY

Methodology for dealing with pH impairments is discussed in Attachment D. Information for the TMDL analysis using the methodology is contained in the TMDLs by segment section in Attachment E.

This TMDL will focus remediation efforts on the identified numerical reduction targets for each watershed. As changes occur in the watershed, the TMDL may be reevaluated to reflect current conditions. Table 3 presents the estimated reductions identified for all points in the watershed. Attachment E gives detailed TMDLs by segment analysis for each allocation point.

Table 3. Summary Table–Solomon Creek Watershed

Station	Parameter	Existing Load (lbs/day)	Allowable Load (lbs/day)	WLA	LA	Load Reduction (lbs/day	Percent Reduction
SC04							
	Fe	0.0	0.0	0	0.0	0.0	0
	Mn	0.7	0.7	0	0.7	0.0	0
	Al	8.8	5.8	0	5.8	3.0	38
	Acidity	491.1	201.4	0	201.4	289.7	59
	Alkalinity	802.7					
SNR							
	Fe	4.3	4.3	0	4.3	0.0	0
	Mn	4.9	2.4	0	2.4	2.5	50
	Al	12.5	1.7	0	1.7	10.8	87
	Acidity	302.1	90.6	0	90.6	211.5	70
	Alkalinity	288.4					
SC03							
	Fe	0.0	0.0	0	0.0	0.0	0*
	Mn	4.6	4.6	0	4.6	0.0	0*
	Al	9.1	6.1	0	6.1	3.0	0*
	Acidity	868.4	197.5	0	197.5	670.9	46*
	Alkalinity	906.4					
SR							
	Fe	128.3	16.7	0	16.7	111.6	87
	Mn	14.0	12.4	0	12.4	1.6	11
	Al	26.8	3.9	0	3.9	22.9	85
	Acidity	0.0	0.0	0	0.0	0.0	0
	Alkalinity	3789.3					
SC02							
	Fe	4.0	4.0	0	4.0	0.0	0*
	Mn	10.5	10.5	0	10.5	0.0	0*
	Al	9.7	6.4	0	6.4	3.3	0*
	Acidity	606.0	363.8	0	363.8	242.2	0*
	Alkalinity	1990.3					
SC01							
	Fe	6356.7	233.2	0	233.2	6123.5	97*
	Mn	699.7	161.3	0	161.3	538.4	77*
	Al	52.1	24.8	0	24.8	24.0	49*
	Acidity	1506.1	1506.1	0	1506.1	0.0	0*
	Alkalinity	22578.5					
Buttonwood Tunnel							
	Fe	9624.0	192.8	0	192.8	9431.2	98
	Mn	1086.0	130.4	0	130.4	955.6	88
	Al	87.9	82.2	0	82.2	5.7	8
	Alkalinity	135660.8					

* Assumes that all reductions from upstream points have been fulfilled.

TMDLS TO ADDRESS SEDIMENT IMPAIRMENT

Pennsylvania's 1996 303(d) list identified 2.4 miles of Solomon Creek as impaired by suspended solids as a result of resource extraction (Table 1). Additional assessments expanded the extent of these impairments. The following sections establish the sediment TMDL addressing impairments from suspended solids and siltation.

APPROACH TO TMDL DEVELOPMENT

A. Pollutants & Sources

Sediment has been identified as the pollutant causing designated use impairments in the Solomon Creek Watershed, with the source listed as resource extraction. At present, there are no point source contributions within the area.

As stated in previous sections, the landscape is dominantly urban/residential and disturbed in the lower portion of the watershed where the sediment impairment exists. The primary source of the sediment are the disturbed lands, with barren/abandoned lots extending right up to the streambanks with little to no riparian buffer zones present. In addition, there are significant volumes of coal waste present on many of these barren/abandoned lots. Based on visual observations, streambank erosion is severe in most reaches of the stream.

B. TMDL Endpoints

In an effort to address the excessive sediment found in Solomon Creek, TMDL loading limits were developed for sediment. The TMDL is intended to address sediment impairments from areas affected by resource extraction first identified in Pennsylvania's 1996 303(d) list, as well as other nonpoint sources such as urban runoff and agriculture.

C. Reference Watershed Approach

The TMDL developed for Solomon Creek watershed addresses sediment. Because neither Pennsylvania nor the USEPA has instream numerical water quality criteria for sediment, a method was developed to implement the applicable narrative criteria. The method for these types of TMDLs is termed the "Reference Watershed Approach." Meeting the water quality objectives specified for this TMDL will result in the impaired stream segment attaining its designated uses.

The Reference Watershed Approach compares two watersheds, one attaining its uses and one that is impaired based on biological assessments. Both watersheds ideally have similar land use/cover distributions. Other features such as base geologic formation should be matched to the extent possible; however, most variations can be adjusted for in the model. The objective of the process is to reduce the loading rate of pollutants in the impaired stream segment to a level equivalent to the loading rate in the nonimpaired, reference stream segment. This load reduction will result in conditions favorable to the return of a healthy biological community to the impaired stream segments.

D. Selection of the Reference Watershed

In general, three factors are considered when selecting a suitable reference watershed. The first factor is to use a watershed that the PADEP has assessed and determined to be attaining water quality standards. The second factor is to find a watershed that closely resembles the impaired watershed in physical properties such as land cover/land use, physiographic province, and geology/soils. Finally, the size of the reference watershed should be within 20-30 percent of the impaired watershed area. The search for a reference watershed for Solomon Creek watershed, that would satisfy the above characteristics, was done by means of a desktop screening using several GIS coverages, including the Multi-Resolution Land Characteristics (MRLC), Landsat-derived land cover/use grid, Pennsylvania's streams database, and geologic rock types.

Abrahams Creek was selected as the reference watershed for developing the Solomon Creek TMDL. Abrahams Creek is located on the opposite side of Wilkes-Barre, northwest of Solomon Creek (Attachment A). As such, the watershed is also located in State Water Plan subbasin 5B, and protected uses include aquatic life and recreation. The tributary is currently designated as cold water fishes (CWF) under §93.9z in Title 25 of the Pa. Code (Commonwealth of Pennsylvania, 2001). Based on PADEP assessments, Abrahams Creek is currently attaining its designated uses. The attainment of designated uses is based on sampling done by the PADEP in 2003, as part of its State Surface Water Assessment Program.

Drainage area, location, and other physical characteristics of Solomon Creek were compared to Abrahams Creek (Table 4). Forest is the dominant land use category in both Abrahams Creek (52 percent) and Solomon Creek (59 percent). The geology, soils, and precipitation in both are also similar (Table 4).

Table 4. Comparison Between Solomon Creek and Abrahams Creek

Attribute	Watershed	
	Solomon Creek	Abrahams Creek
Physiographic Province	Ridge and Valley (100%)	Ridge and Valley (100%)
Area (mi^2)	~18	~17
Land Use	Forested (59%) Agriculture (7%) Development (26%) Disturbed (7%)	Forested (51%) Agriculture (26%) Development (18%) Disturbed (2%)
Geology	Interbedded Sedimentary 77 % Remaining is Sandstone	Interbedded Sedimentary 94% Remaining is Sandstone
Soils	Chenango-Pope-Holly Udorthents-Urban Land-Volusia Lackawanna-Arnot-Morris	Chenango-Pope-Holly Udorthents-Urban Land-Volusia Lackawanna-Arnot-Morris Volusia-Mardin-Lordstown
Dominant HSG	B D C	B D C C
K Factor	0.17 - 0.30	0.17 – 0.30
20-Yr. Ave. Rainfall (in)	41.63	41.63
20-Yr. Ave. Runoff (in)	4.84	3.46

WATERSHED ASSESSMENT AND MODELING

The TMDL for Solomon Creek watershed was developed using the ArcView Generalized Watershed Loading Function model (AVGWLF) as described in Attachment G. The AVGWLF model was used to establish existing loading conditions for Solomon Creek watershed and the reference Abrahams Creek watershed. All modeling inputs have been attached to this TMDL as Attachments H and I. SRBC staff compared aerial photography and 2001 state landuse coverages for Solomon Creek and Abrahams Creek watersheds. SRBC determined that the landuse of Abrahams Creek matched the aerial photography of the watershed. However, while reviewing the landuse coverage for Solomon Creek and comparing with aerial photographs and field observations, SRBC determined that approximately 400 acres of transitional/barren lands were incorrectly classified as "low-intensity residential". SRBC elected to change the landuse acreage in the model to reflect actual conditions, in order to calculate a more accurate measure of loadings in the Solomon Creek watershed.

The AVGWLF model produced information on watershed size, land use, and sediment loading. The sediment load represents an annual average over a 20-year period (1978 to 1998) for Solomon Creek and a 20-year period (1978 to 1998) for Abrahams Creek. This information was then used to calculate existing unit area loading rates for Solomon Creek and Abrahams Creek watersheds. Sediment loading information for both the impaired watershed and the reference watershed are shown in Tables 5 and 6, respectively.

Table 5. Existing Sediment Loads for Solomon Creek

		Sediment	
Pollutant Source	**Acreage**	**Mean Annual Loading (lbs/day)**	**Unit Area Loading (lbs/ac/day)**
HAY/PAST	509.00	260,580.00	511.94
CROPLAND	336.10	1,661,280.00	4,942.81
FOREST	6,748.40	397,820.00	58.95
WETLAND	76.60	2,140.00	27.94
QUARRY	215.00	1,181,120.00	5,493.58
COAL_MINES	64.20	252,240.00	3,928.97
TURF_GRASS	22.20	240.00	10.81
TRANSITION	491.70	11,246,260.00	22,872.20
LO_INT_DEV	1,838.50	152,100.00	82.73
HI_INT_DEV	1,173.70	43,120.00	36.74
Tile Drainage		0.00	
Stream Bank		2,638,640.12	
Groundwater			
Point Source			
Septic Systems			
TOTAL	11,475.40	17,835,540.12	1,554.24

Table 6. Existing Sediment Loads for Abrahams Creek

Pollutant Source	Acreage	Sediment	
		Mean Annual Loading (lbs/day)	Unit Area Loading (lbs/ac/day)
HAY/PAST	1,527.10	599,240.00	392.40
CROPLAND	1,391.20	5,256,620.00	3,778.48
FOREST	5,651.30	330,880.00	58.55
WETLAND	24.70	360.00	14.57
QUARRY	24.70	22,540.00	912.55
COAL_MINES	12.40	18,420.00	1,485.48
TURF_GRASS	2.50	20.00	8.00
UNPAVED_RD	7.40	63,260.00	8,548.65
TRANSITION	237.20	5,597,060.00	23,596.37
LO_INT_DEV	1,774.20	93,440.00	52.67
HI_INT_DEV	180.40	3,980.00	22.06
Tile Drainage		0.00	
Stream Bank		1,747,891.12	
Groundwater			
Point Source			
Septic Systems			
TOTAL	10,833.10	13,733,711.12	1,267.75

TMDLS

Targeted TMDL values for Solomon Creek watershed were established based on current loading rates for sediment in the Abrahams Creek reference watershed. Biological assessments have determined that Abrahams Creek is currently attaining its designated uses. Reducing the loading rate of sediment in Solomon Creek watershed to levels equivalent to those in the reference watershed will provide conditions favorable for the reversal of current use impairments.

A. Background Pollutant Conditions

There are two separate considerations of background pollutants within the context of this TMDL. First, there is the inherent assumption of the reference watershed approach that because of the similarities between the reference and impaired watershed, the background pollutant contributions will be similar. Therefore, the background pollutant contributions will be considered when determining the loads for the impaired watershed that are consistent with the loads from the reference watershed. Second, the AVGWLF model implicitly considers background pollutant contributions through the soil and the groundwater component of the model process.

B. Targeted TMDLs

Targeted TMDL value for sediment was determined by multiplying the total area of Solomon Creek watershed (11475.40 acres) by the appropriate unit area loading rate for the Abrahams Creek reference watershed (Table 7). The existing mean annual loading of sediment to Solomon Creek (17,835,540.12 lbs/day) will need to be reduced by 18 percent to meet the targeted TMDL of 14,547,938.35 lbs/day.

Table 7. Targeted Sediment TMDL for the Solomon Creek Watershed

Pollutant	Area (ac)	Unit Area Loading Rate Abrahams Creek Watershed (lbs/ac/day)	Targeted TMDL for Solomon Creek (lbs/day)
Sediment	11475.40	1267.75	14,547,938.35

The targeted TMDL value was used as the basis for load allocations and reductions in the Solomon Creek watershed, using the following two equations:

1. TMDL = LA + MOS
2. LA = ALA + LNR

where:

TMDL = Total Maximum Daily Load
LA = Load Allocation (nonpoint sources)
ALA = Adjusted Load Allocation
LNR = Loads not Reduced

C. Margin of Safety (MOS)

The MOS is that portion of the pollutant loading that is reserved to account for any uncertainty in the data and computational methodology used for the analysis. For this analysis, the MOS is explicit. Ten percent of the targeted TMDL for sediment was reserved as the MOS. Using 10 percent of the TMDL load is based on professional judgment and will provide an additional level of protection to the designated uses of Solomon Creek. The MOS used for the sediment TMDL was 1,454,793.84 lbs/day, respectively.

MOS (sediment) = 14,547,938.35 lbs/day (TMDL) x 0.1 = 1,454,793.84 lbs/day

D. Load Allocation

The LA is that portion of the TMDL that is assigned to nonpoint sources. The LA was computed by subtracting the WLA and MOS values from the targeted TMDL value. The LA for sediment was 13,093,144.51 lbs/yr.

LA (sediment) = 14,547,938.35 lbs/yr (TMDL) – 1,454,793.84 lbs/yr (MOS) = 13,093,144.51 lbs/yr

E. Adjusted Load Allocation (ALA)

The ALA is the actual portion of the LA distributed among those nonpoint sources receiving reductions. It is computed by subtracting those nonpoint source loads that are not being considered for reductions (loads not reduced or LNR) from the LA. Sediment reductions were made to the hay/pasture, cropland, developed areas (sum of LO_INT_DEV, HI_INT_DEV and TURF_GRASS), disturbed areas (sum of QUARRY, COAL_MINES, and TRANSITION) and streambanks. Those land uses/sources for which existing loads were not reduced (FOREST AND WETLAND) were carried through at their existing loading values (Table 8). The ALA for sediment was 12,693,184.51 lbs/day.

Table 8. LA, LNR, and ALA for Solomon Creek

	Sediment (lbs/day)
Load Allocation	13,093,144.51
Loads Not Reduced	399,960.00
FOREST	397820.00
WETLAND	2140.00
Adjusted Load Allocation	12,693,184.51

F. TMDLs

The sediment TMDL established for the Solomon Creek watershed consists of a LA, and a MOS. The individual components of the TMDL are summarized in Table 9.

Table 9 TMDL, MOS, LA, LNR, and ALA for Solomon Creek

Component	Sediment (lbs/day)
TMDL (Total Maximum Daily Load)	14,547,938.35
MOS (Margin of Safety)	1,454,793.84
LA (Load Allocation)	13,093,144.51
LNR (Loads Not Reduced)	399,960.00
ALA (Adjusted Load Allocation)	12,693,184.51

CALCULATION OF SEDIMENT LOAD REDUCTIONS

The ALA established in the previous section represents the annual total sediment load that is available for allocation between contributing sources in the Solomon Creek watershed. The ALA for sediment was allocated between agriculture, developed areas, disturbed lands and streambanks. LA and reduction procedures were applied to the entire Solomon Creek watershed using the Equal Marginal Percent Reduction (EMPR) allocation method (Attachment J). The LA and EMPR procedures were performed using MS Excel and results are presented in Attachment K.

To meet the sediment TMDL, the current loading from controllable sources will require a reduction to 12,693,184.51 lbs/day. This is achievable through sediment load reductions of 27 percent for cropland, hay/pasture, developed lands, disturbed lands and streambanks (Table 10).

Table 10. Sediment Load Allocations & Reductions for Solomon Creek

Pollutant Source	Acres	Unit Area Loading Rate (lbs/ac/day)		Pollutant Loading (lbs/day)		% Reduction
		Current	Allowable	Current	Allowable (LA)	
Sediment						
Hay/Past	509.00	511.94	372.70	260,580.00	189,703.47	27%
Cropland	336.10	4,942.81	3,598.39	1,661,280.00	1,209,419.67	27%
Developed	3,034.40	64.41	46.89	195,460.00	142,295.80	27%
Disturbed	770.90	16,447.81	11,974.09	12,679,620.00	9,230,823.13	27%
Streambank				2,638,640.12	1,920,942.44	27%
Total				17,435,580.12	12,693,184.51	27%

CONSIDERATION OF CRITICAL CONDITIONS

The AVGWLF model is a continuous simulation model, which uses daily time steps for weather data and water balance calculations. Monthly calculations are made for sediment loads, based on the daily water balance accumulated to monthly values. Therefore, all flow conditions are taken into account for loading calculations. Because there is generally some lag time between the introduction of sediment to a waterbody and the resulting impact on beneficial uses, establishing this TMDL using average annual conditions is protective of the waterbody.

CONSIDERATION OF SEASONAL VARIATIONS

The continuous simulation model used for these analyses considers seasonal variation through a number of mechanisms. Daily time steps are used for weather data and water balance calculations. The model requires specification of the growing season and hours of daylight for each month. The model also considers the months of the year when manure is applied to the land. The combination of these actions by the model accounts for seasonal variability.

RECOMMENDATIONS

There is currently no watershed group in the Solomon Creek Watershed. However, the Wyoming Valley Watershed Coalition (WVWC) is an active group in this area. The WVWC conducted Streamside Cleanups in the Solomon Creek Watershed in 2003 and 2004. The Earth Conservancy has been working in the watershed as well. They completed construction on Phase I of the Greater Hanover Recreation Park in 2001 that encompasses 15 acres. Phase II of the project is under construction and will comprise about 48 acres. This park is being built on reclaimed mined areas. These watershed organizations could continue to work in the watershed to implement projects to achieve the reductions recommended in this TMDL document. Continuing with the current projects within the watershed is strongly recommended.

The PADEP BAMR administers an environmental regulatory program for all mining activities, including mine subsidence regulation, mine subsidence insurance, and coal refuse disposal. PADEP BAMR also conducts a program to ensure safe underground bituminous mining and protect certain structures from subsidence; administers a mining license and permit program; administers a regulatory program for the use, storage, and handling of explosives; and provides for training, examination, and certification of applicant's blaster's licenses. In addition, PADEP BAMR administers a loan program for bonding anthracite underground mines and for mine subsidence, administers the USEPA Watershed Assessment Grant Program, the Small Operator's Assistance Program (SOAP), and the Remining Operator's Assistance Program (ROAP).

Reclaim PA is PADEP's initiative designed to maximize reclamation of the state's quarter million acres of abandoned mineral extraction lands. Abandoned mineral extraction lands in Pennsylvania constitute a significant public liability - more than 250,000 acres of abandoned surface mines, 2,400 miles of stream polluted with AMD, over 7,000 orphaned and abandoned oil and gas wells, widespread subsidence problems, numerous hazardous mine openings, mine fires, abandoned structures, and affected water supplies – representing as much as one third of the total problem nationally.

Since the 1960's, Pennsylvania has been a national leader in establishing laws and regulations to ensure mine reclamation and well plugging occur after active operation is completed. Mine reclamation and well plugging refers to the process of cleaning up environmental pollutants and safety hazards associated with a site and returning the land to a productive condition, similar to PADEP's Brownfields Program. Pennsylvania is striving for complete reclamation of its abandoned mines and plugging of its orphan wells. Realizing this task is no small order, PADEP has developed Reclaim PA, a collection of concepts to make abandoned mine reclamation easier. These concepts include legislative, policy, and land management initiatives designed to enhance mine operator/volunteer/PADEP reclamation efforts. Reclaim PA has the following four objectives:

- To encourage private and public participation in abandoned mine reclamation efforts.
- To improve reclamation efficiency through better communication between reclamation partners.
- To increase reclamation by reducing remining risks.

- To maximize reclamation funding by expanding existing sources and exploring new sources.

PUBLIC PARTICIPATION

In the beginning stages of the Solomon Creek Watershed TMDL, an early notification letter was sent to inform stakeholders and interested parties that a TMDL would be completed in their watershed and offer them the opportunity to submit information for TMDL development. The PADEP considered all the information submitted by EPCAMR and WVWC, and all pertinent information was included in the report.

Public notice of the draft TMDL was published in the *Pennsylvania Bulletin* on November 6, 2004, and The Citizen's Voice on November 5, 2004, to foster public comment on the allowable loads calculated. A public meeting was held on November 10, 2004, at the Hanover Township Building in Hanover Township, Pa., to discuss the proposed TMDL.

REFERENCES

Bruns, Dale, Tom Sweet, and Bill Toothill. 2001. Upper Susquehanna-Lackawanna River Watershed. Section 206 Ecosystem Restoration Report.

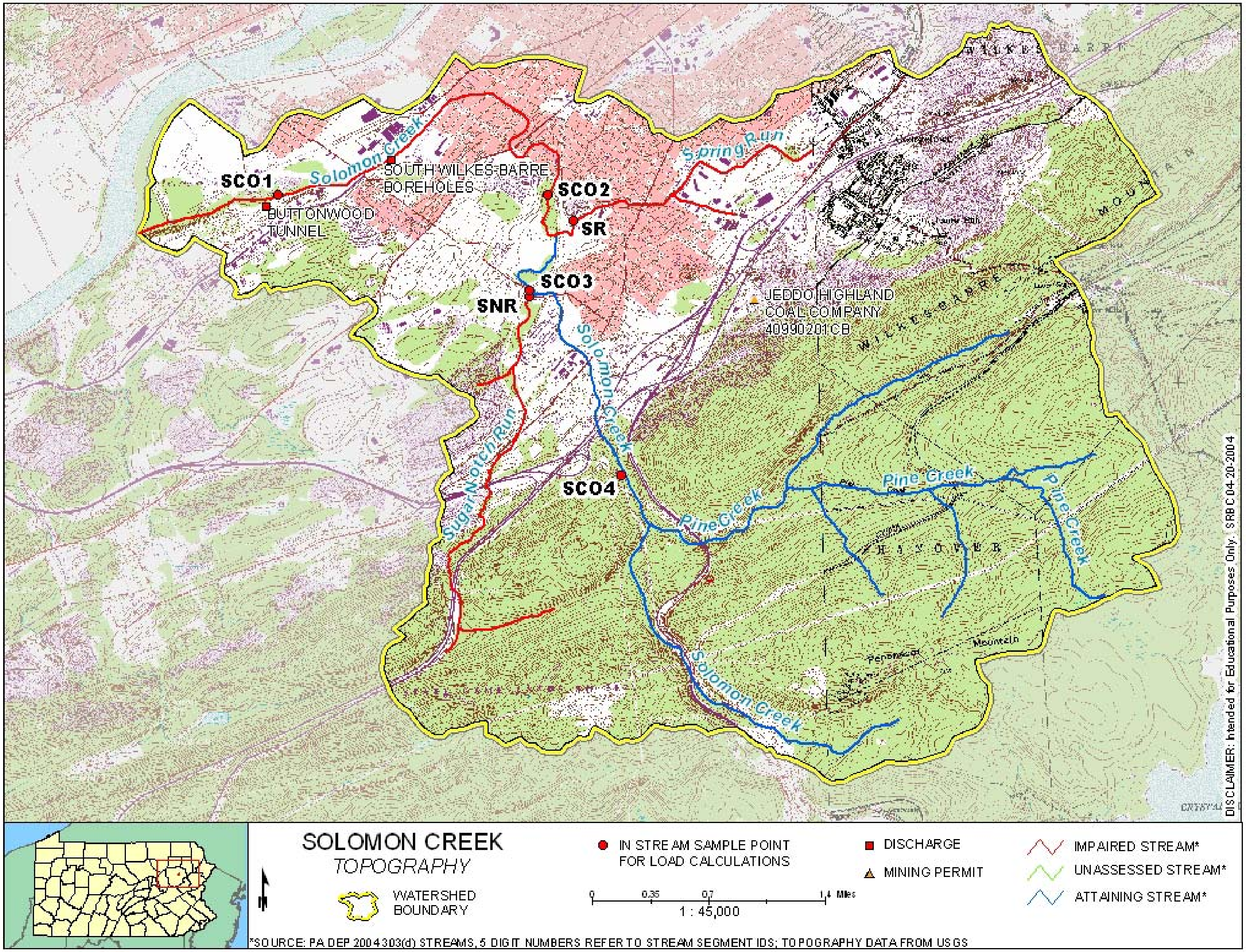
GEO-Technical Services Consulting Engineers and Geologists. 1975. Study of Acid Mine Abatement for Nanticoke, Warrior, and Solomon Creeks. Operation Scarlift Project No. SL 181-3.

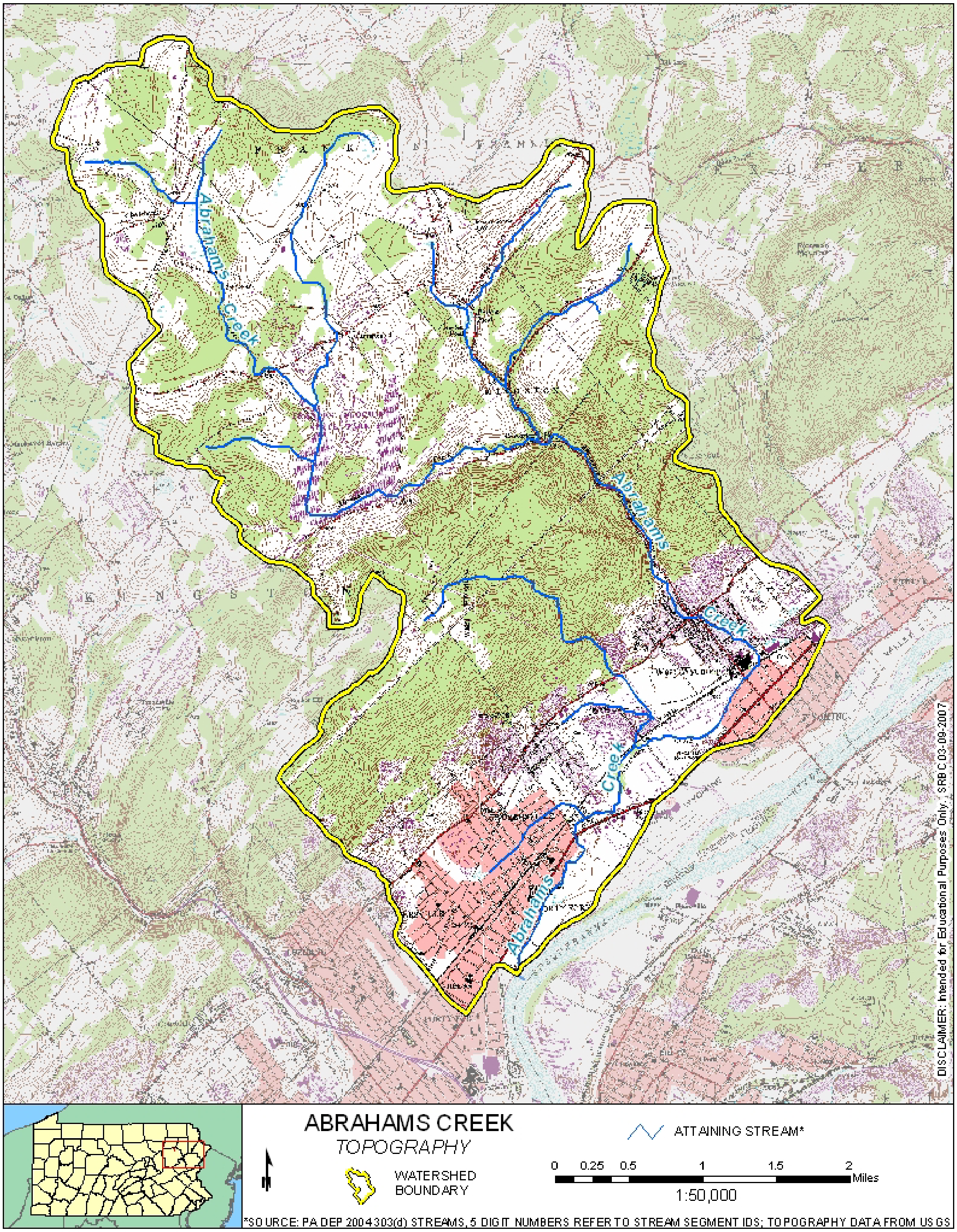
Hughes, Robert, Mike Hewitt, and Teresa Genna. 2003. A Snapshot Assessment of Freshwater Macro-invertebrate Populations in the Urban, Disturbed Wyoming Valley Watershed, Luzerne County, PA Due to Non-Point Source Pollution Impacts.

Wood, Charles R. 1996. Water Quality of Large Discharges from Mines in the Anthracite Region of Eastern Pennsylvania. U.S. Geological Survey Water-Resources Investigations Report 95-4243.

Attachment A

Solomon and Abrahams Watershed Maps


SOLOMON CREEK
TOPOGRAPHY
WATERSHED BOUNDARY
IN STREAM SAMPLE POINT FOR LOAD CALCULATIONS
DISCHARGE
MINING PERMIT
IMPAIRED STREAM*
UNASSESSED STREAM*
ATTAINING STREAM*
0 0.35 0.7 1.4 Miles
1 : 45,000
*SOURCE: PA DEP 2004 303(d) STREAMS, 5 DIGIT NUMBERS REFER TO STREAM SEGMENT IDS; TOPOGRAPHY DATA FROM USGS
DISCLAIMER: Intended for Educational Purposes Only. SRBC 04-20-2004
SCO1
SCO2
SCO3
SCO4
SR
SNR
BUTTONWOOD TUNNEL
SOUTH WILKES-BARRE BOREHOLES
JEDDO HIGHLAND COAL COMPANY 40990201CB
Solomon Creek
Spring Run
Sugar Notch Run
Pine Creek
WILKES-BARRE
MOUNTAIN



Abrahams Creek
Abrahams Creek
Abrahams Creek
DISCLAIMER: Intended for Educational Purposes Only, SRBC 03-09-2007
ABRAHAMS CREEK
TOPOGRAPHY
WATERSHED BOUNDARY
ATTAINING STREAM*
0 0.25 0.5 1 1.5 2 Miles
1:50,000
*SOURCE: PA DEP 2004 303(d) STREAMS, 5 DIGIT NUMBERS REFER TO STREAM SEGMENT IDS; TOPOGRAPHY DATA FROM USGS

Attachment B

Excerpts Justifying Changes Between the 1996, 1998, 2002, and 2004 Section 303(d) Lists

The following are excerpts from the Pennsylvania DEP 303(d) narratives that justify changes in listings between the 1996, 1998, 2002, and 2004 lists. The 303(d) listing process has undergone an evolution in Pennsylvania since the development of the 1996 list.

In the 1996 303(d) narrative, strategies were outlined for changes to the listing process. Suggestions included, but were not limited to, a migration to a Global Information System (GIS), improved monitoring and assessment, and greater public input.

The migration to a GIS was implemented prior to the development of the 1998 303(d) list. As a result of additional sampling and the migration to the GIS some of the information appearing on the 1996 list differed from the 1998 list. Most common changes included:

1. mileage differences due to recalculation of segment length by the GIS;
2. slight changes in source(s)/cause(s) due to new USEPA codes;
3. changes to source(s)/cause(s), and/or miles due to revised assessments;
4. corrections of misnamed streams or streams placed in inappropriate SWP subbasins; and
5. unnamed tributaries no longer identified as such and placed under the named watershed listing.

Prior to 1998, segment lengths were computed using a map wheel and calculator. The segment lengths listed on the 1998 303(d) list were calculated automatically by the GIS (ArcInfo) using a constant projection and map units (meters) for each watershed. Segment lengths originally calculated by using a map wheel and those calculated by the GIS did not always match closely. This was the case even when physical identifiers (e.g., tributary confluence and road crossings) matching the original segment descriptions were used to define segments on digital quad maps. This occurred to some extent with all segments, but was most noticeable in segments with the greatest potential for human errors using a map wheel for calculating the original segment lengths (e.g., long stream segments or entire basins). The 2002 Pa. Section 303(d) list was written in a manner similar to the 1998 Section 303(d) list.

In 2004, Pennsylvania developed the Integrated List of All Waters. The water quality status of Pennsylvania's waters is summarized using a five-part categorization of waters according to their water quality standard (WQS) attainment status. The categories represent varying levels of WQS attainment, ranging from Category 1, where all designated water uses are met, to Category 5, where impairment by pollutants requires a TMDL to correct. These category determinations are based on consideration of data and information consistent with the methods outlined by the Statewide Surface Water Assessment Program. Each PADEP five-digit waterbody segment is placed in one of the WQS attainment categories. Different segments of the same stream may appear on more than one list if the attainment status changes as the water flows downstream. The listing categories are as follows:

Category 1: Waters attaining all designated uses.

Category 2: Waters where some, but not all, designated uses are met. Attainment status of the remaining designated uses is unknown because data are insufficient to categorize a water consistent with the state's listing methodology.

Category 3: Waters for which there are insufficient or no data and information to determine, consistent with the state's listing methodology, if designated uses are met.

Category 4: Waters impaired for one or more designated use but not needing a TMDL. States may place these waters in one of the following three subcategories:

- TMDL has been completed.
- Expected to meet all designated uses within a reasonable timeframe.
- Not impaired by a pollutant.

Category 5: Waters impaired for one or more designated uses by any pollutant. Category 5 includes waters shown to be impaired as the result of biological assessments used to evaluate aquatic life use even if the specific pollutant is not known unless the state can demonstrate that nonpollutant stressors cause the impairment or that no pollutant(s) causes or contribute to the impairment. Category 5 constitutes the Section 303(d) list that USEPA will approve or disapprove under the Clean Water Act. Where more than one pollutant is causing the impairment, the water remains in Category 5 until all pollutants are addressed in a completed USEPA-approved TMDL or one of the delisting factors is satisfied.

Attachment C

Mining Permit in the Solomon Creek Watershed

Permit Number	Company Name	Status
40990201CB	Jeddo-Highland Coal Company	Active

Attachment D

Method for Addressing 303(d) Listings for pH

Method for Addressing 303(d) Listings for pH

There has been a great deal of research conducted on the relationship between alkalinity, acidity, and pH. Research published by the Pa. Department of Environmental Protection demonstrates that by plotting net alkalinity (alkalinity-acidity) vs. pH for 794 mine sample points, the resulting pH value from a sample possessing a net alkalinity of zero is approximately equal to six (Figure 1). Where net alkalinity is positive (greater than or equal to zero), the pH range is most commonly six to eight, which is within the USEPA's acceptable range of six to nine and meets Pennsylvania water quality criteria in Pa. Code, Chapter 93.

The pH, a measurement of hydrogen ion acidity presented as a negative logarithm, is not conducive to standard statistics. Additionally, pH does not measure latent acidity. For this reason, and based on the above information, Pennsylvania is using the following approach to address the stream impairments noted on the 303(d) list due to pH. The concentration of acidity in a stream is at least partially chemically dependent upon metals. For this reason, it is extremely difficult to predict the exact pH values, which would result from treatment of abandoned mine drainage. Therefore, net alkalinity will be used to evaluate pH in these TMDL calculations. This methodology assures that the standard for pH will be met because net alkalinity is a measure of the reduction of acidity. When acidity in a stream is neutralized or is restored to natural levels, pH will be acceptable. Therefore, the measured instream alkalinity at the point of evaluation in the stream will serve as the goal for reducing total acidity at that point. The methodology that is applied for alkalinity (and therefore pH) is the same as that used for other parameters such as iron, aluminum, and manganese that have numeric water quality criteria.

Each sample point used in the analysis of pH by this method must have measurements for total alkalinity and total acidity. Net alkalinity is alkalinity minus acidity, both being in units of milligrams per liter (mg/l) $CaCO_3$. The same statistical procedures that have been described for use in the evaluation of the metals is applied, using the average value for total alkalinity at that point as the target to specify a reduction in the acid concentration. By maintaining a net alkaline stream, the pH value will be in the range between six and eight. This method negates the need to specifically compute the pH value, which for mine waters is not a true reflection of acidity. This method assures that Pennsylvania's standard for pH is met when the acid concentration reduction is met.

There are several documented cases of streams in Pennsylvania having a natural background pH below six. If the natural pH of a stream on the 303(d) list can be established from its upper unaffected regions, then the pH standard will be expanded to include this natural range. The acceptable net alkalinity of the stream after treatment/abatement in its polluted segment will be the average net alkalinity established from the stream's upper, pristine reaches. Summarized, if the pH in an unaffected portion of a stream is found to be naturally occurring below six, then the average net alkalinity for that portion of the stream will become the criterion for the polluted portion. This "natural net alkalinity level" will be the criterion to which a 99 percent confidence level will be applied. The pH range will be varied only for streams in which a natural unaffected net alkalinity level can be established. This can only be done for streams that have upper segments that are not impacted by mining activity. All other streams will be required to meet a minimum net alkalinity of zero.

Reference: *Rose, Arthur W. and Charles A. Cravotta, III 1998. Geochemistry of Coal Mine Drainage. Chapter 1 in Coal Mine Drainage Prediction and Pollution Prevention in Pennsylvania. Pa. Dept. of Environmental Protection, Harrisburg, Pa.*

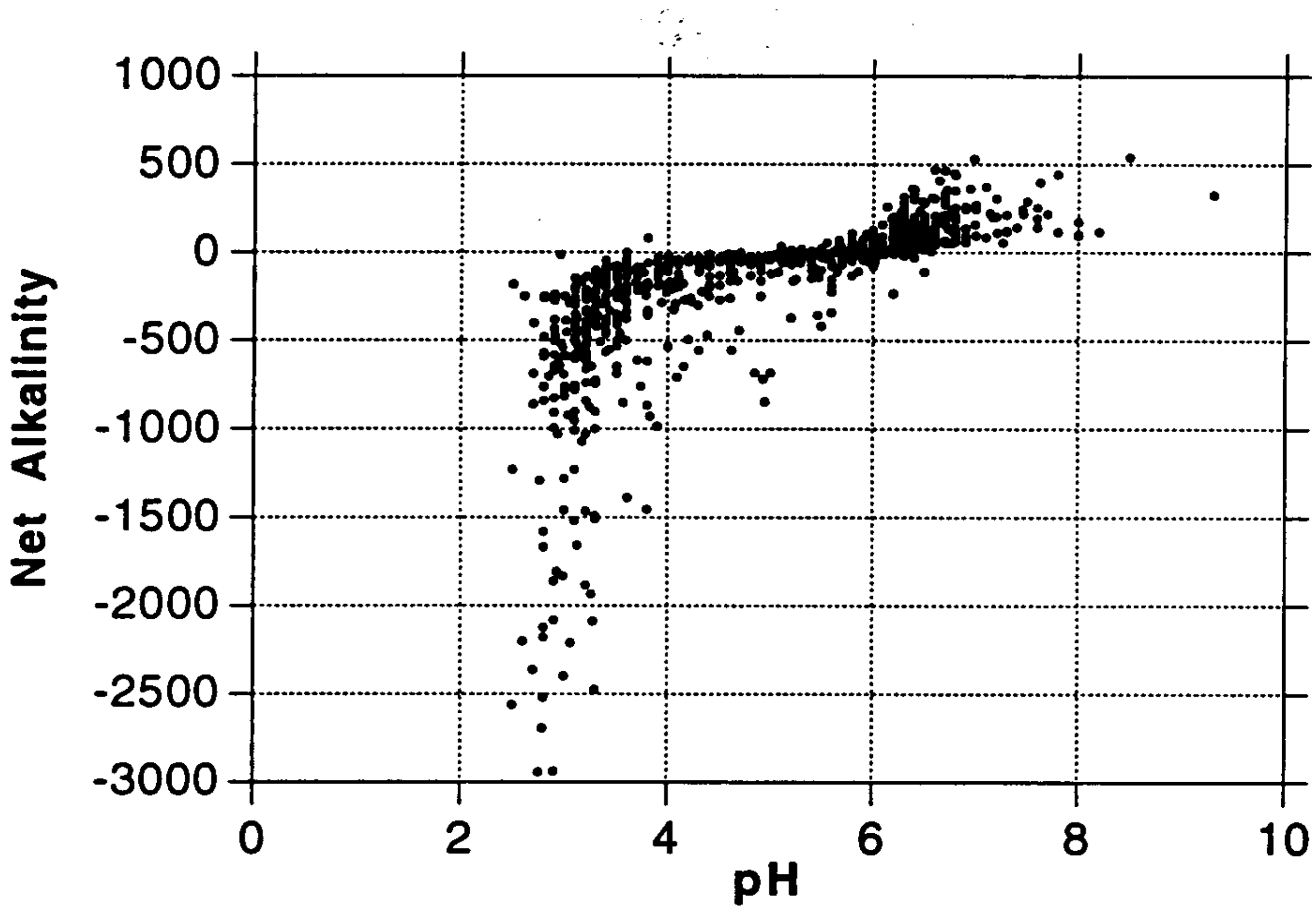


Figure 1. Net Alkalinity vs. pH. Taken from Figure 1.2 Graph C, pages 1-5, of Coal Mine Drainage Prediction and Pollution Prevention in Pennsylvania.

Attachment E
TMDLs by Segment

Solomon Creek above SR04

Solomon Creek above point SC04 has been determined to be meeting its designated use. The headwaters of Solomon Creek are located in a heavily forested area that is sparsely populated. The forested area consists of both coniferous and deciduous trees.

The TMDL for this section of Solomon Creek consists of a load allocation to all of the watershed area above point SC04. Addressing the causes of high acidity above this point, such as coniferous forests and sandstone geology with little buffering capacity, addresses the impairment. An instream flow measurement was available for point SC04 (8.75 mgd).

An allowable long-term average instream concentration for iron, manganese, aluminum, and acidity was determined at point SC04. The analysis is designed to produce a long-term average value that, when met, will be protective of the water quality criterion for that parameter 99 percent of the time. An analysis was performed using Monte Carlo simulation to determine the necessary long-term average concentration needed to attain water quality criteria 99 percent of the time. The simulation was run assuming the data set was lognormally distributed. Using the mean and the standard deviation of the data set, 5,000 iterations of sampling were completed and compared against the water quality criterion for that parameter. For each sampling event a percent reduction was calculated, if necessary, to meet water quality criteria. A second simulation that multiplied the percent reduction times the sampled value was run to insure that criteria were met 99 percent of the time. The mean value from this data set represents that long-term daily average concentration that needs to be met to achieve water quality standards. The load allocations made at point SC04 for this stream segment are presented in Table E1.

Table E1. Reductions for Solomon Creek Above SC04

	Measured Sample Data		***Allowable***		***Reduction Identified***
	Conc. (mg/l)	***Load (lb/day)***	***LTA Conc. (mg/l)***	***Load (lb/day)***	***Percent***
Fe	0.00	0.0	0.00	0.0	0
Mn	0.01	0.7	0.01	0.73	0
Al	0.12	8.8	0.08	5.8	38
Acidity	6.73	491.1	2.76	201.4	59
Alkalinity	11.0	802.7			

All values shown in this table are long-term average daily values.

The iron concentration on all samples was below the detection limit of 0.30 mg/l, therefore, it can be assumed that the segment is not impaired by iron.

The TMDL for Solomon Creek at point SC04 requires that a load allocation be made for all areas above SC04 for total aluminum and total acidity.

Sugar Notch Run above SNR

Sugar Notch Run is a tributary to Solomon Creek that enters directly upstream of point SC03. Sugar Notch Run had been assessed at the time of this report and determined to be impaired by AMD. The headwaters start in a forested area, but the stream flows through abandoned mine fields. A large quantity of flow is lost to underground mines from cracks in the streambed. Cracks in the streambed can measure up to four inches (GEO-Technical, 1975). When the water in Sugar Notch Run reaches Solomon Creek, it has been severely degraded by AMD.

The TMDL for Sugar Notch Run consists of a load allocation to all of the watershed area above point SNR. Addressing the mining impacts above this point addresses the impairment for the segment. An instream flow measurement was available for point SNR (1.17 mgd).

An allowable long-term average instream concentration for iron, manganese, aluminum, and acidity was determined at point SNR. The analysis is designed to produce a long-term average value that, when met, will be protective of the water quality criterion for that parameter 99 percent of the time. An analysis was performed using Monte Carlo simulation to determine the necessary long-term average concentration needed to attain water quality criteria 99 percent of the time. The simulation was run assuming the data set was lognormally distributed. Using the mean and the standard deviation of the data set, 5,000 iterations of sampling were completed and compared against the water quality criterion for that parameter. For each sampling event a percent reduction was calculated, if necessary, to meet water quality criteria. A second simulation that multiplied the percent reduction times the sampled value was run to insure that criteria were met 99 percent of the time. The mean value from this data set represents that long-term daily average concentration that needs to be met to achieve water quality standards. The load allocations made at point SNR for this stream segment are presented in Table E2.

Table E2. Reductions for Sugar Notch Run Above SNR

	Measured Sample Data		***Allowable***		***Reduction Identified***
	Conc. (mg/l)	***Load (lb/day)***	***LTA Conc. (mg/l)***	***Load (lb/day)***	***Percent***
Fe	0.44	4.3	0.44	4.3	0
Mn	0.50	4.9	0.25	2.4	50
Al	1.28	12.5	0.17	1.7	87
Acidity	30.96	302.1	9.29	90.6	70
Alkalinity	29.56	288.4			

All values shown in this table are long-term average daily values.

The TMDL for Sugar Notch Run at point SNR requires that a load allocation be made for all areas above SNR for total manganese, total aluminum, and total acidity.

Solomon Creek Between SC04 and SC03

Solomon Creek between SC04 and SC03 represents Solomon Creek between points SC04 and SC03. Sugar Notch Run, a source of AMD, empties into this segment of Solomon Creek. Solomon Creek has been determined to be meeting its designated use.

The TMDL for this section of Solomon Creek consists of a load allocation to all of the watershed area between SC04 and SC03. Addressing the mining impacts between these points addresses the impairment from the segment. An instream flow measurement was available for point SC03 (9.11 mgd).

An allowable long-term average instream concentration for iron, manganese, aluminum, and acidity was determined at point SC03. The analysis is designed to produce a long-term average value that, when met, will be protective of the water quality criterion for that parameter 99 percent of the time. An analysis was performed using Monte Carlo simulation to determine the necessary long-term average concentration needed to attain water quality criteria 99 percent of the time. The simulation was run assuming the data set was lognormally distributed. Using the mean and the standard deviation of the data set, 5,000 iterations of sampling were completed and compared against the water quality criterion for that parameter. For each sampling event a percent reduction was calculated, if necessary, to meet water quality criteria. A second simulation that multiplied the percent reduction times the sampled value was run to insure that criteria were met 99 percent of the time. The mean value from this data set represents that long-term daily average concentration that needs to be met to achieve water quality standards. The load allocations made at point SC03 for this stream segment are presented in Table E3.

E3. Long Term Average (LTA) for Solomon Creek Between SC04 and SC03

	Measured Sample Data		***Allowable***	
	Conc. (mg/l)	***Load (lb/day)***	***LTA Conc. (mg/l)***	***Load (lb/day)***
Fe	0.00	0.0	0.00	0.0
Mn	0.06	4.6	0.06	4.6
Al	0.12	9.1	0.08	6.1
Acidity	11.43	868.4	2.6	197.5
Alkalinity	11.93	906.4		

All values shown in this table are long-term average daily values.

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The iron concentrations for all samples were below the detection limit of 0.30 mg/l, therefore, it can be assumed that the segment is not impaired by iron.

The loading reductions for points SC04 and SNR were used to show the total load that was removed from upstream sources. For each parameter, the total load that was removed upstream was subtracted from the existing load at point SC03. This value was compared to the allowable load at point SC03. Reductions at point SC03 are necessary for any parameter that exceeds the allowable load at this point. Necessary reductions at point SC03 are shown in Table E4.

Table E4. Reductions Necessary at Point SC03				
	Iron (lb/day)	***Manganese (lb/day)***	***Aluminum (lb/day)***	***Acidity (lb/day)***
Existing Load at SC03	0.0	4.6	9.1	868.4
Existing load from upstream points (SC04 & SNR)	4.3	5.6	21.3	793.2
Difference of existing load and upstream existing load	-4.3	-1.0	-12.2	75.2
Percent load loss due to instream process	100	18	58	0
Allowable loads from upstream points	4.3	3.1	7.5	292.0
Percent load remaining at SC03	0	82	42	100
Total load at SC03	0	2.5	3.2	367.2
Allowable load at SC03	0	4.6	6.1	197.5
Load Reduction at SC03 (Total load at SC03 – Allowable load at SC03)	0	0	0	169.70
Percent Reduction required at SC03	0	0	0	46

The TMDL for Solomon Creek at point SC03 requires that a load allocation be made for all areas above SC03 for total acidity.

Spring Run above SR

Spring Run is a tributary to Solomon Creek that empties into the creek below point SC03. Spring Run flows through abandoned surface and deep mined areas. Most of the flow in the stream is lost to deep mines before it reaches its confluence with Solomon Creek. Spring Run has been severely impacted by AMD.

The TMDL for Spring Run consists of a load allocation to all of the watershed area above point SR. Addressing mining impacts above this point addresses the impairment for the segment. No instream flow measurement was available for point SR. The AVGWLF model was used to calculate a flow for Spring Run (4.66 mgd).

An allowable long-term average instream concentration was determined at point SR for iron, manganese, aluminum, and acidity. The analysis is designed to produce a long-term average value that, when met, will be protective of the water quality criterion for that parameter 99 percent of the time. An analysis was performed using Monte Carlo simulation to determine the necessary long-term average concentration needed to attain water quality criteria 99 percent of the time. The simulation was run assuming the data set was lognormally distributed. Using the mean and the standard deviation of the data set, 5,000 iterations of sampling were completed and compared against the water quality criterion for that parameter. For each sampling event a percent reduction was calculated, if necessary, to meet water quality criteria. A second simulation that multiplied the percent reduction times the sampled value was run to insure that criteria were met 99 percent of the time. The mean value from this data set represents that long-term daily average concentration that needs to be met to achieve water quality standards. The load allocations made at SR for this stream segment are presented in Table E5.

Table E5. Reductions for Spring Run Above SR					
	Measured Sample Data		***Allowable***		***Reduction Identified***
	Conc. (mg/l)	***Load (lb/day)***	***LTA Conc. (mg/l)***	***Load (lb/day)***	***Percent***
Fe	3.30	128.3	0.43	16.7	87
Mn	0.36	14.0	0.32	12.4	11
Al	0.69	26.8	0.10	3.9	85
Acidity	0.0	0.0	0.0	0.0	0
Alkalinity	97.5	3,789.3			

All values shown in this table are long-term average daily values.

The TMDL for Spring Run at point SR requires that a load allocation be made for all areas above SR for total iron, total manganese, and total aluminum.

Solomon Creek Between SC03 and SC02

Solomon Creek between SC03 and SC02 represents Solomon Creek after receiving water from Spring Run. There are no additional sources of AMD for this segment of Solomon Creek.

The TMDL for this section of Solomon Creek consists of a load allocation to all of the watershed area between SC03 and SC02. Addressing the mining impacts between these points addresses the impairment for the segment. An instream flow measurement was available for point SC02 (9.65 mgd).

An allowable long-term average instream concentration was determined at point SC02 for iron, manganese, aluminum, and acidity. The analysis is designed to produce a long-term average value that, when met, will be protective of the water quality criterion for that parameter 99 percent of the time. An analysis was performed using Monte Carlo simulation to determine the necessary long-term average concentration needed to attain water quality criteria 99 percent of the time. The simulation was run assuming the data set was lognormally distributed. Using the mean and the standard deviation of the data set, 5,000 iterations of sampling were completed and compared against the water quality criterion for that parameter. For each sampling event a percent reduction was calculated, if necessary, to meet water quality criteria. A second simulation that multiplied the percent reduction times the sampled value was run to insure that criteria were met 99 percent of the time. The mean value from this data set represents that long-term daily average concentration that needs to be met to achieve water quality standards. The load allocations made at SC02 for this stream segment are presented in Table E6.

Table E6. Long Term Average (LTA) for Solomon Creek Between SC03 and SC02				
	Measured Sample Data		***Allowable***	
	Conc.(mg/l)	***Load (lb/day)***	***LTA Conc. (mg/l)***	***Load(lb/day)***
Fe	0.05	4.0	0.05	4.0
Mn	0.13	10.5	0.13	10.5
Al	0.12	9.7	0.08	6.4
Acidity	7.53	606.0	4.52	363.8
Alkalinity	24.73	1,990.3		

All values shown in this table are long-term average daily values.

The loading reductions for points SC03 and SR were used to show the total load that was removed from upstream sources. For each parameter, the total load that was removed upstream was subtracted from the existing load at point SC02. The value was compared to the allowable load at point SC02. Reductions at point SC02 are necessary for any parameter that exceeds the allowable load at this point. Necessary reductions at point SC02 are shown in Table E7.

Table E7. Reductions Necessary at Point SC02				
	Iron (lb/day)	***Manganese (lb/day)***	***Aluminum (lb/day)***	***Acidity (lb/day)***
Existing Loads at SC02	4.0	10.5	9.7	606.0
Existing load from upstream points (SC03 & SR)	128.3	18.6	35.9	868.4
Difference of existing load and upstream existing load	-124.3	-8.1	-26.2	-262.4
Percent load loss due to instream process	97	44	73	30
Allowable load from upstream points	16.7	17.0	10.0	197.5
Percent load remaining at SC02	3	56	27	70
Total load at SC02	0.5	9.5	2.7	138.3
Allowable load at SC02	4.0	10.5	6.4	363.8
Load Reduction at SC02 (Total load at SC02 – Allowable load at SC02)	0	0	0	0
Percent Reduction required at SC02	0	0	0	0

The TMDL for Solomon Creek at point SC02 does not require that a load allocation be made between SC03 and SC02.

Solomon Creek Between SC02 and SC01

Solomon Creek between SC02 and SC01 receives three additional sources of AMD. The three South Wilkes-Barre boreholes add significant amounts of AMD impacted water to Solomon Creek. The South Wilkes-Barre boreholes were drilled by the state of Pennsylvania in order to control basement flooding.

Prior to the drilling of the boreholes, Solomon Creek Watershed was not severely degraded by AMD. The mine pool outflow was distributed along the banks of the Susquehanna River and its tributaries. These mine pool outflows are now a point discharge at the boreholes (GEO-

Technical, 1975). There are two Mine Pool Complexes in the Solomon Creek area: the North-West Mine Pool Complex and the South-East Mine Pool Complex.

The discharge from the South Wilkes-Barre boreholes began in June 1972 and comes from the South-East Mine Pool Complex. Approximately 70 percent of the mine water in the complex originates in the bordering watershed of Mill Creek (GEO-Technical, 1975). The boreholes measure 36 inches in diameter each and in 1991 were discharging 20 cfs (Wood, 1996).

The TMDL for this section of Solomon Creek consists of a load allocation to all of the watershed area above point SC01. Addressing the mining impacts above this point addresses the impairment for the segment. An instream flow measurement was available for point SC01 (29.75 mgd).

An allowable long-term average instream concentration for iron, manganese, aluminum, and acidity was determined at point SC01. The analysis is designed to produce a long-term average value that, when met, will be protective of the water quality criterion for that parameter 99 percent of the time. An analysis was performed using Monte Carlo simulation to determine the necessary long-term average concentration needed to attain water quality criteria 99 percent of the time. The simulation was run assuming the data set was lognormally distributed. Using the mean and the standard deviation of the data set, 5,000 iterations of sampling were completed and compared against the water quality criterion for that parameter. For each sampling event a percent reduction was calculated, if necessary, to meet water quality criteria. A second simulation that multiplied the percent reduction times the sampled value was run to insure that criteria were met 99 percent of the time. The mean value from this data set represents that long-term daily average concentration that needs to be met to achieve water quality standards. The load allocations made at point SC01 for this stream segment are presented in Table E8.

Table E8. Long Term Average (LTA) Concentrations for Solomon Creek Between SC02 and SC01

	Measured Sample Data		***Allowable***	
	Conc. (mg/l)	***Load (lb/day)***	***LTA Conc. (mg/l)***	***Load (lb/day)***
Fe	25.62	6,356.7	0.94	233.2
Mn	2.82	699.7	0.65	161.3
Al	0.21	52.1	0.10	24.8
Acidity	6.07	1,506.1	6.07	1,506.1
Alkalinity	91.0	22,578.5		

All values shown in this table are long-term average daily values.

The loading reductions for point SC02 were used to show the total load that was removed from upstream sources. For each parameter, the total load that was removed upstream was subtracted from the existing load at point SC01. This value was compared to the allowable load at point SC01. Reductions at point SC01 are necessary for any parameter that exceeds the allowable load at this point. Necessary reductions at point SC01 are shown in Table E9.

Table E9. Reductions Necessary at Point SC01				
	Iron (lb/day)	***Manganese (lb/day)***	***Aluminum (lb/day)***	***Acidity (lb/day)***
Existing Loads at SC01	6356.7	699.7	52.1	1506.1
Existing load from upstream point (SC02)	4.0	10.5	9.7	606.0
Difference of existing load and upstream existing load	6352.7	689.2	42.4	900.1
Allowable load from upstream points	4.0	10.5	6.4	363.8
Total load at SC01	6356.7	699.7	48.8	1263.9
Allowable load at SC01	233.2	161.3	24.8	1506.1
Load Reduction at SC01 (Total load at SC01 – Allowable load at SC01)	6123.5	538.4	24.0	0
Percent Reduction required at SC01	97	77	49	0

The TMDL for Solomon Creek at point SC01 requires that a load allocation be made for all areas between SC02 and SC01 for total iron, total manganese, and total aluminum.

Buttonwood Tunnel Outlet Discharge

The Buttonwood Tunnel Outlet discharge comes from the North-West Mine Pool Complex. This mine pool is recharged by water lost to deep mines from the Susquehanna River and began discharging in the fall of 1967. It discharges directly into Solomon Creek, adding a significant amount of AMD impacted water to the stream.

The Buttonwood Tunnel Outlet was drilled by the state of Pennsylvania for the same purpose the South Wilkes-Barre boreholes were drilled - to control basement flooding. The TMDL consists of a load allocation to the Buttonwood Tunnel. Addressing the discharge addresses the impairment. A discharge flow measurement was available for point Buttonwood Tunnel (34.00 mgd).

Instream point SC01 addresses all AMD impairments with the exception of the Buttonwood Tunnel. There are no flow or water quality data for Solomon Creek below the Buttonwood Tunnel discharge. However, there are data available for the discharge and it was used to calculate metal loads entering Solomon Creek. Flow and water chemistry data for the Buttonwood Tunnel Outlet were not available for parallel dates. Recent flow data for the discharge (May 2003 to April 2004) was used to calculate the average flow. Average metal concentrations were calculated using water chemistry data available during the same time period.

An allowable long-term average instream concentration for iron, manganese, and aluminum, was determined at the Buttonwood Tunnel Outlet. The analysis is designed to produce a long-term average value that, when met, will be protective of the water quality criterion for that parameter 99 percent of the time. An analysis was performed using Monte Carlo simulation to determine the necessary long-term average concentration needed to attain water quality criteria 99 percent of the time. The simulation was run assuming the data set was lognormally distributed. Using the mean and the standard deviation of the data set, 5,000 iterations of sampling were completed and compared against the water quality criterion for that parameter. For each sampling event a percent reduction was calculated, if necessary, to meet water quality criteria. A second simulation that multiplied the percent reduction times the sampled value was run to insure that criteria were met 99 percent of the time. The mean value from this data set represents that long-term daily average concentration that needs to be met to achieve water quality standards. The load allocations made at point SC01 for this stream segment are presented in Table E10.

Table E10. Reductions for Buttonwood Tunnel Outlet					
	Measured Sample Data		*Allowable*		*Reduction Identified*
	Conc. (mg/l)	*Load (lb/day)*	*LTA Conc. (mg/l)*	*Load (lb/day)*	*Percent*
Fe	33.94	9,624.0	0.68	192.8	98
Mn	3.83	1,086.0	0.46	130.4	88
Al	0.31	87.9	0.29	82.2	8
Alkalinity	478.42	135,660.8			

All values shown in this table are long-term average daily values.

The TMDL for Solomon Creek at Buttonwood Tunnel requires that a load allocation be made for total iron, total manganese, and total aluminum.

Margin of Safety (MOS)

For each TMDL calculated in this study the MOS is applied implicitly. A MOS is built in because the allowable concentrations and loadings were simulated using Monte Carlo techniques and by employing the @Risk software. Other margins of safety used for this TMDL analysis include the following:

- Effluent variability plays a major role in determining the average value that will meet water-quality criteria over the long term. The value that provides this variability in our analysis is the standard deviation of the dataset. The simulation results are based on this variability and the existing stream conditions (an uncontrolled system). The general assumption can be made that a controlled system (one that is controlling and stabilizing the pollution load) would be less variable than an uncontrolled system. This implicitly builds in a margin of safety.
- A MOS is also the fact that the calculations were performed with a daily iron average instead of the 30 day average.

Seasonal Variation

Seasonal variation is implicitly accounted for in each TMDL because the data used represent all seasons.

Critical Conditions

The reductions specified in each TMDL apply at all flow conditions. A critical flow condition could not be identified from the data used for this analysis.

Attachment F

Water Quality Data Used
In TMDL Calculations

TMDL Site	Study Point	Company	Permit #	Date	Flow (gpm)	Acid (mg/l)	Alk (mg/l)	Fe (mg/l)	Mn (mg/l)	Al (mg/l)	pH
SC01	SOLO1.0	SRBC-604(b) Report	*	11/28/2001	8678.6	0.0	104	31.6	3.58	0.723	6.4
	SOLO1.0	SRBC-604(b) Report	*	2/19/2002	15716.27	0.0	100	29.3	3.43	0	6.5
	SOLO1.0	SRBC-604(b) Report	*	4/3/2002	20604.45	16	86	23.5	2.63	0	6.3
	SOLO1.0	SRBC-604(b) Report	*	5/2/2002	37775.29	20.4	56	13.2	1.33	0.532	6.3
	SOLO1.0	SRBC-604(b) Report	*	6/11/2002	27074.08	0.0	86	23.2	2.5	0	6.3
	SOLO1.0	SRBC-604(b) Report	*	7/16/2002	14092.67	0.0	114	32.9	3.46	0	6.4
				Average=	20.656.89	6.07	91.0	25.62	2.82	0.21	6.4
				StDev=	10442.23	9.50	20.27	7.31	0.86	0.33	0.1
SC02	SOLO2.0	SRBC-604(b) Report	*	11/28/2001	684.47	0.0	26	0	0.133	0.723	6.7
	SOLO2.0	SRBC-604(b) Report	*	2/19/2002	3683.56	0.0	13.8	0	0.089	0	6.5
	SOLO2.0	SRBC-604(b) Report	*	4/3/2002	6624.84	17.2	15.2	0	0.091	0	6.0
	SOLO2.0	SRBC-604(b) Report	*	5/2/2002	20130.75	15.2	13.6	0.317	0.078	0	6.3
	SOLO2.0	SRBC-604(b) Report	*	6/11/2002	8778.42	12.8	11.8	0	0.165	0	6.3
	SOLO2.0	SRBC-604(b) Report	*	7/16/2002	294.57	0.0	68	0	0.198	0	7.4
				Average=	6699.44	7.53	24.7	0.05	0.13	0.12	6.5
				StDev=	7362.41	8.37	21.80	0.13	0.05	0.30	0.5
SC03	SOLO3.0	SRBC-604(b) Report	*	11/28/2001	860.41	0.0	13.6	0	0	0.726	6.6
	SOLO3.0	SRBC-604(b) Report	*	2/19/2002	3589.75	9.4	10.8	0	0.055	0	6.4
	SOLO3.0	SRBC-604(b) Report	*	4/3/2002	7185.29	24.4	12.0	0	0.104	0	5.9
	SOLO3.0	SRBC-604(b) Report	*	5/2/2002	17469.9	16.2	10.6	0	0.057	0	6.2
	SOLO3.0	SRBC-604(b) Report	*	6/11/2002	8775.73	19.6	9.2	0	0.13	0	5.9
	SOLO3.0	SRBC-604(b) Report	*	7/16/2002	78.64	0.0	15.4	0	0	0	6.8
				Average=	6326.62	11.43	11.93	0	0.06	0.12	6.3
				StSev=	6439.18	10.08	2.25	0.0	0.05	0.30	0.4
SC04	SOLO4.0	SRBC-604(b) Report	*	11/28/2001	1014.36	0.0	11.0	0	0	0.747	6.5
	SOLO4.0	SRBC-604(b) Report	*	2/19/2002	*3236.07	8.0	10.0	0	0	0	6.2
	SOLO4.0	SRBC-604(b) Report	*	4/3/2002	*6152.67	11.4	11.6	0	0	0	5.8
	SOLO4.0	SRBC-604(b) Report	*	5/2/2002	14424.72	10.0	9.8	0	0	0	6.1
	SOLO4.0	SRBC-604(b) Report	*	6/11/2002	8425.37	11.0	9.8	0	0.064	0	6.1
	SOLO4.0	SRBC-604(b) Report	*	7/16/2002	390.93	0.0	13.8	0	0	0	6.9

TMDL Site	Study Point	Company	Permit #	Date	Flow (gpm)	Acid (mg/l)	Alk (mg/l)	Fe (mg/l)	Mn (mg/l)	Al (mg/l)	pH
				Average=	5607.35	6.73	11.0	0	0.01	0.12	6.3
				StDev=	5289.88	5.35	1.55	0.0	0.03	0.31	0.4
SNR	SGNR1.0	SRBC-604(b) Report	*	11/28/2001	4.49	0.0	104	0	0.057	0.94	7.0
	SGNR1.0	SRBC-604(b) Report	*	2/19/2002	208.26	38.0	11.6	0.667	0.736	2.36	6.2
	SGNR1.0	SRBC-604(b) Report	*	4/3/2002	676.93	51.4	12.0	0.469	0.442	0.596	5.8
	SGNR1.0	SRBC-604(b) Report	*	5/2/2002	2290.16	34.2	12.4	0.335	0.222	0	6.2
	SGNR1.0	SRBC-604(b) Report	*	6/11/64	888.64	31.2	4.8	0.72	1.05	2.51	4.7
				Average =	813.70	30.96	29.56	0.44	0.50	1.28	6.0
				StDev =	898.00	18.95	41.65	0.29	0.40	1.11	0.8
SR	SPRR1.0	SRBC-604(b) Report	*	2/19/2002	**	0.0	140.0	6.54	0.551	0.519	6.7
	SPRR1.0	SRBC-604(b) Report	*	4/3/2002	**	0.0	118.0	3.04	0.441	0	6.5
	SPRR1.0	SRBC-604(b) Report	*	5/2/2002	**	0.0	24.0	1.47	0.055	2.22	6.5
	SPRR1.0	SRBC-604(b) Report	*	6/11/2002	**	0.0	108.0	2.13	0.404	0	6.7
				Average=	**	0.0	97.5	3.30	0.36	0.69	6.6
				StDev=	**	0.0	50.79	2.26	0.21	1.05	0.1
Buttonwood Tunnel	Buttonwood Tunnel	Borton Lawson Engineering	*	5/21/2003	14,857	*	*	*	*	*	*
	Buttonwood Tunnel	Borton Lawson Engineering	*	10/15/2003	*	*	260	29.2	3.11	0.343	5.6
	Buttonwood Tunnel	Borton Lawson Engineering	*	10/29/2003	*	*	500	47.3	4.9	0.66	6.1
	Buttonwood Tunnel	Borton Lawson Engineering	*	11/14/2003	*	*	984	29.3	3.63	0.32	6.1
	Buttonwood Tunnel	Borton Lawson Engineering	*	12/1/2003	*	*	448	35.41	3.11	0.34	6.1
	Buttonwood Tunnel	Borton Lawson Engineering	*	12/16/2003	*	*	830	47.2	3.87	0.32	5.9
	Buttonwood Tunnel	Borton Lawson Engineering	*	12/19/2003	34,649	*	*	*	*	*	*
	Buttonwood Tunnel	Borton Lawson Engineering	*	12/29/2003	*	*	499	17.1	3.3	0.0284	6.1
	Buttonwood Tunnel	Borton Lawson Engineering	*	1/13/2004	*	*	759	55.6	3.71	0.32	5.9
	Buttonwood Tunnel	Borton Lawson Engineering	*	1/29/2004	*	*	1091	27.01	3.42	0.346	6.2
	Buttonwood Tunnel	Borton Lawson Engineering	*	2/16/2004	*	*	65	28.1	7.56	0.355	6.2
	Buttonwood Tunnel	Borton Lawson Engineering	*	2/27/2004	12,655	*	*	*	*	*	*
	Buttonwood Tunnel	Borton Lawson Engineering	*	3/1/2004	*	*	106	29.76	2.89	0.1	6.8
	Buttonwood Tunnel	Borton Lawson Engineering	*	3/3/2004	19,078	*	*	*	*	*	*
	Buttonwood Tunnel	Borton Lawson Engineering	*	3/11/2004	41,537	*	*				
	Buttonwood Tunnel	Borton Lawson Engineering	*	3/15/2004	*	*	114	26.3	2.63	0.31	6.4

TMDL Site	Study Point	Company	Permit #	Date	Flow (gpm)	Acid (mg/l)	Alk (mg/l)	Fe (mg/l)	Mn (mg/l)	Al (mg/l)	pH
	Buttonwood Tunnel	Borton Lawson Engineering	*	3/18/2004	22,547	*	*	*	*	*	*
	Buttonwood Tunnel	Borton Lawson Engineering	*	3/30/2004	*	*	85	35.0	3.79	0.324	6.3
	Buttonwood Tunnel	Borton Lawson Engineering	*	4/6/2004	19,821	*	*	*	*	*	*
	Buttonwood Tunnel	Borton Lawson Engineering	*	4/15/2004	23,726	*	*	*	*	*	*
				Average=	23,609	*	478.42	33.94	3.83	0.31	6.14
				StDev=	9,826.37	*	366.79	10.92	1.31	0.15	0.29

"*" signifies no data were collected

"**"No flow data available; AVGWLF model used to calculate flow.

Note: All concentrations are in units of milligrams per liter (mg/l); all discharge measurements are in units of gallons per minute (GPM)

Attachment G

AVGWLF Model Overview & GIS-Based Derivation on Input Data

The TMDL for Solomon Creek was developed using the Generalized Watershed Loading Function or GWLF model. The GWLF model provides the ability to simulate runoff, sediment, and nutrient (nitrogen and phosphorus) loadings from watershed given variable-size source areas (e.g., agricultural, forested, and developed land). It also has algorithms for calculating septic system loads, and allows for the inclusion of point source discharge data. It is a continuous simulation model, which uses daily time steps for weather data and water balance calculations. Monthly calculations are made for sediment and nutrient loads, based on the daily water balance accumulated to monthly values.

GWLF is a combined distributed/lumped parameter watershed model. For surface loading, it is distributed in the sense that it allows multiple land use/cover scenarios. Each area is assumed to be homogenous in regard to various attributes considered by the model. Additionally, the model does not spatially distribute the source areas, but aggregates the loads from each area into a watershed total. In other words, there is no spatial routing. For subsurface loading, the model acts as a lumped parameter model using a water balance approach. No distinctly separate areas are considered for subsurface flow contributions. Daily water balances are computed for an unsaturated zone as well as a saturated subsurface zone, where infiltration is computed as the difference between precipitation and snowmelt minus surface runoff plus evapotranspiration.

GWLF models surface runoff using the Soil Conservation Service Curve Number (SCS-CN) approach with daily weather (temperature and precipitation) inputs. Erosion and sediment yield are estimated using monthly erosion calculations based on the Universal Soil Loss Equation (USLE) algorithm (with monthly rainfall-runoff coefficients) and a monthly composite of KLSCP values for each source area (e.g., land cover/soil type combination). The KLSCP factors are variables used in the calculations to depict changes in soil loss erosion (K), the length slope factor (LS), the vegetation cover factor (C) and conservation practices factor (P). A sediment delivery ratio based on watershed size, transport capacity, and average daily runoff is applied to the calculated erosion for determining sediment yield for each source area. Surface nutrient losses are determined by applying dissolved nitrogen and phosphorus coefficients to surface runoff and a sediment coefficient to the yield portion for each agricultural source area. Point source discharges also can contribute to dissolved losses to the stream and are specified in terms of kilograms per month. Manured areas, as well as septic systems, can also be considered. Urban nutrient inputs are all assumed to be solid-phase, and the model uses an exponential accumulation and washoff function for these loadings. Subsurface losses are calculated using dissolved nitrogen and phosphorus coefficients for shallow groundwater contributions to stream nutrient loads, and the subsurface submodel only considers a single, lumped-parameter contributing area. Evapotranspiration is determined using daily weather data and a cover factor dependent upon land use/cover type. Finally, a water balance is performed daily using supplied or computed precipitation, snowmelt, initial unsaturated zone storage, maximum available zone storage, and evapotranspiration values. All of the equations used by the model can be viewed in GWLF Users Manual.

For execution, the model requires three separate input files containing transport-, nutrient-, and weather-related data. The transport (TRANSPRT.DAT) file defines the necessary parameters for each source area to be considered (e.g., area size, curve number, etc.) as well as global parameters (e.g., initial storage, sediment delivery ratio, etc.) that apply to all source areas. The nutrient (NUTRIENT.DAT) file specifies the various loading parameters for the different source areas identified (e.g., number of septic systems, urban source area accumulation rates, manure concentrations, etc.). The weather (WEATHER.DAT) file contains daily average temperature and total precipitation values for each year simulated.

The primary sources of data for this analysis were geographic information system (GIS) formatted databases. A specially designed interface was prepared by the Environmental Resources Research Institute of the Pennsylvania State University in ArcView (GIS software) to generate the data needed to run the GWLF model, which was developed by Cornell University. The new version of this model has been named AVGWLF (ArcView Version of the Generalized Watershed Loading Function).

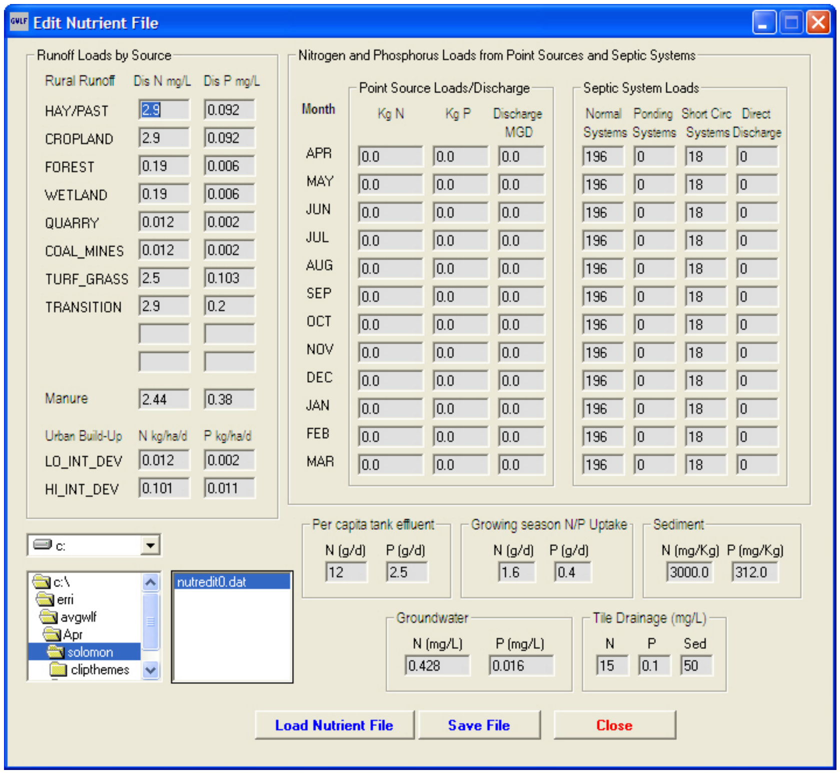
In using this interface, the user is prompted to identify required GIS files and to provide other information related to "non-spatial" model parameters (e.g., beginning and end of the growing season, the months during which manure is spread on agricultural land, and the names of nearby weather stations). This information is subsequently used to automatically derive values for required model input parameters, which are then written to the TRANSPRT.DAT, NUTRIENT.DAT and WEATHER.DAT input files needed to execute the GWLF model. For use in Pennsylvania, AVGWLF has been linked with statewide GIS data layers such as land use/cover, soils, topography, and physiography; and includes location-specific default information such as background nitrogen and phosphorus concentrations and cropping practices. Complete GWLF-formatted weather files also are included for 80 weather stations around the state.

The following table lists the statewide GIS data sets and provides an explanation of how they were used for development of the input files for the GWLF model.

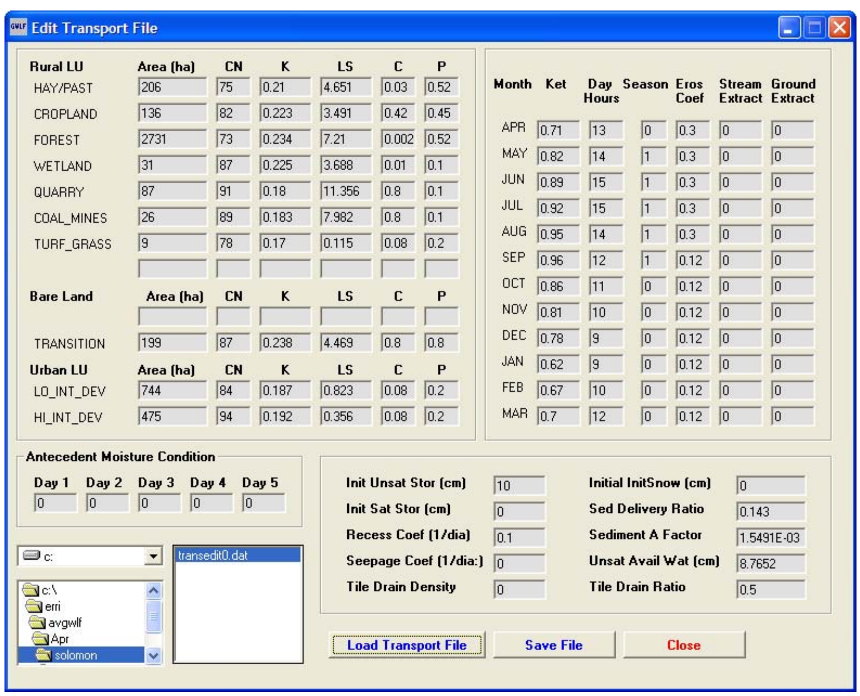
GIS Data Sets	
DATASET	**DESCRIPTION**
Censustr	Coverage of Census data including information on individual homes septic systems. The attribute *usew_sept* includes data on conventional systems, and *sew_other* provides data on short-circuiting and other systems.
County	The County boundaries coverage lists data on conservation practices, which provides C and P values in the Universal Soil Loss Equation (USLE).
Gwnback	A grid of background concentrations of N in groundwater derived from water well sampling.
Landuse5	Grid of the MRLC that has been reclassified into five categories. This is used primarily as a background.
Majored	Coverage of major roads. Used for reconnaissance of a watershed.
MCD	Minor civil divisions (boroughs, townships and cities).
Npdespts	A coverage of permitted point discharges. Provides background information and cross check for the point source coverage.
Padem	100-meter digital elevation model. Used to calculate landslope and slope length.
Palumrlc	A satellite image derived land cover grid that is classified into 15 different land cover categories. This dataset provides land cover loading rate for the different categories in the model.
Pasingle	The 1:24,000 scale single line stream coverage of Pennsylvania. Provides a complete network of streams with coded stream segments.
Physprov	A shapefile of physiographic provinces. Attributes *rain_cool* and *rain_warm* are used to set recession coefficient
Pointsrc	Major point source discharges with permitted nitrogen and phosphorus loads.
Refwater	Shapefile of reference watersheds for which nutrient and sediment loads have been calculated.
Soilphos	A grid of soil phosphorous loads, which has been generated from soil sample data. Used to help set phosphorus and sediment values.
Smallsheds	A coverage of watersheds derived at 1:24,000 scale. This coverage is used with the stream network to delineate the desired level watershed.
Statsgo	A shapefile of generalized soil boundaries. The attribute *mu_k* sets the k factor in the USLE. The attribute *mu_awc* is the unsaturated available capacity, and the *muhsg_dom* is used with land use cover to derive curve numbers.
Strm305	A coverage of stream water quality as reported in the Pennsylvania's 305(b) report. Current status of assessed streams.
Surfgeol	A shapefile of the surface geology used to compare watersheds of similar qualities.
T9sheds	Data derived from a PADEP study conducted at PSU with N and P loads.
Zipcode	A coverage of animal densities. Attribute *aeu_acre* helps estimate N & P concentrations in runoff in agricultural lands and over manured areas.
Weather Files	Historical weather files for stations around Pennsylvania to simulate flow.

Attachment H
AVGWLF Model Inputs for Solomon Creek

Solomon Creek Nutrient



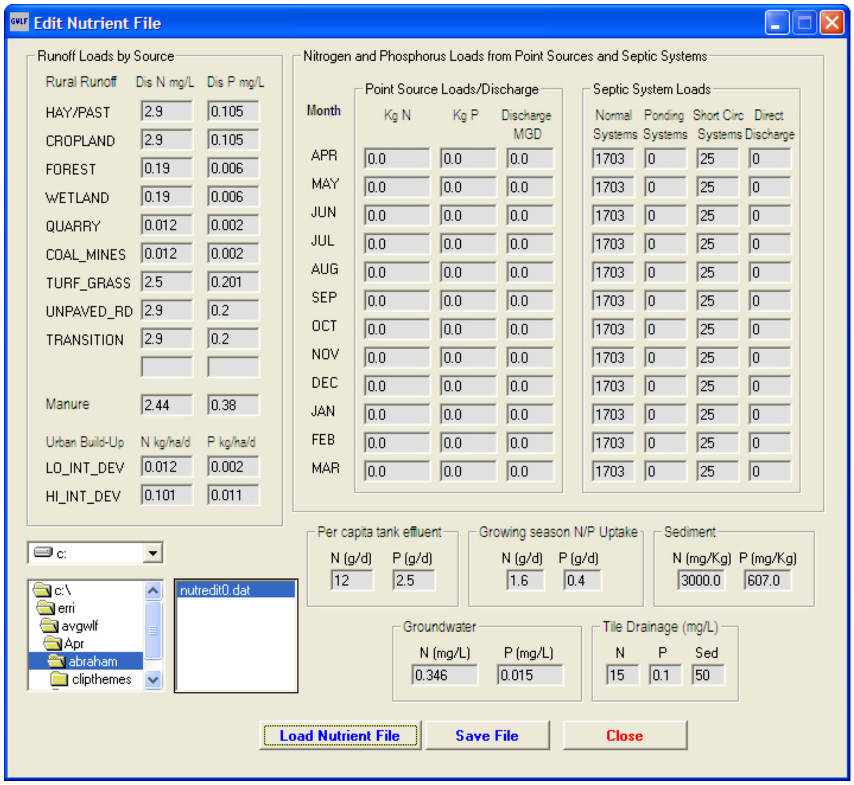
Solomon Creek Transport



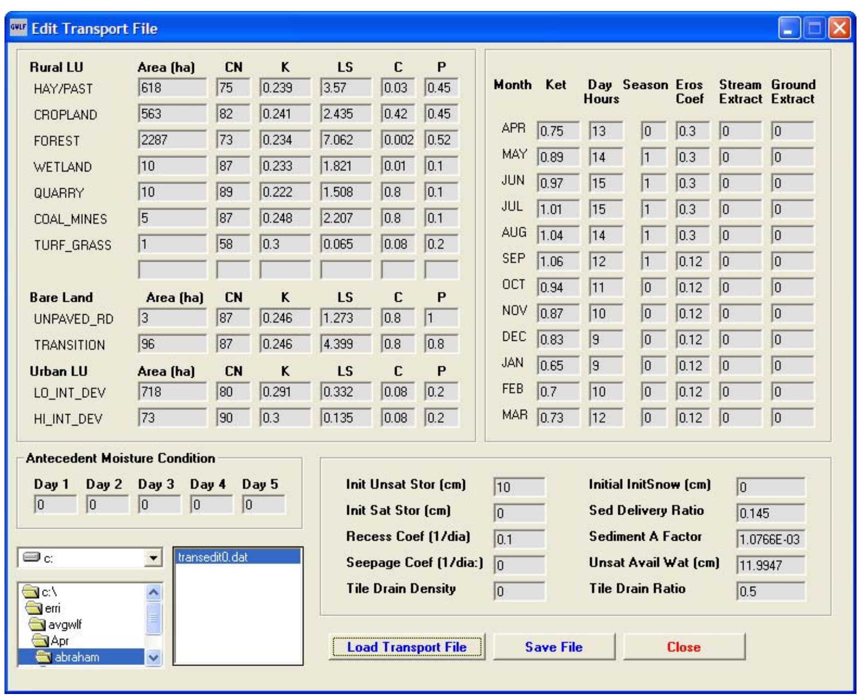
Attachment I

AVGWLF Model Inputs for the Abrahams Creek Reference Watershed

Abrahams Creek Nutrient



Abrahams Creek Transport



Attachment J

Equal Marginal Percent Reduction Method

The Equal Marginal Percent Reduction (EMPR) allocation method was used to distribute Adjusted Load Allocations (ALAs) between the appropriate contributing nonpoint sources. The load allocation and EMPR procedures were performed using the MS Excel and results are presented in Attachment K. The five major steps identified in the spreadsheet are summarized below:

1. Calculation of the TMDL based on impaired watershed size and unit area loading rate of the reference watershed.

2. Calculation of ALA based on TMDL, Margin of Safety, and existing loads not reduced.

3. Actual EMPR Process.

    a. Each land use/source load is compared with the total ALA to determine if any contributor would exceed the ALA by itself. The evaluation is carried out as if each source is the only contributor to the pollutant load of the receiving waterbody. If the contributor exceeds the ALA, that contributor would be reduced to the ALA. If a contributor is less than the ALA, it is set at the existing load. This is the baseline portion of the EMPR.
    b. After any necessary reductions have been made in the baseline, the multiple analyses are run. The multiple analyses will sum all of the baseline loads and compare them to the ALA. If the ALA is exceeded, an equal percent reduction will be made to all contributors' baseline values. After any necessary reductions in the multiple analyses, the final reduction percentage for each contributor can be computed.

4. Calculation of total loading rate of all sources receiving reductions.

5. Summary of existing loads, final load allocations, and percent reduction for each pollutant source.

Attachment K

Equal Marginal Percent Reduction Calculations

Step 1:	TMDL Total Load				Step 2:	Adjusted LA = (TMDL total load - MOS) - uncontrollable						
	Load = loading rate in ref. * Acres in Impaired					12693184.51	12693185					
	14547938											
	SEDIMENT LOADING											
Step 3:		Non-MS4 Annual Average Load	Load Sum	Check	Initial Adjust	Recheck	% reduction allocation	Load Reduction	Initial LA	Acres	Allowable Loading Rate	% Reduction
	Hay/Past.	260580.00	17435580.12	good	260580	ADJUST	0.01	70876.53	189703.47	509.00	372.70	27%
	Cropland	1661280.00		good	1661280	4742396	0.10	451860.33	1209419.67	336.10	3598.39	27%
	Developed	195460.00		good	195460		0.01	53164.20	142295.80	3034.40	46.89	27%
	Disturbed	12679620.00		good	12679620		0.73	3448796.87	9230823.13	770.90	11974.09	27%
	Streambank	2638640.12		good	2638640		0.15	717697.68	1920942.44			27%
	Total	17435580.12			17435580.12		1.00		12693184.51			

Step 4:		Acres	Allowable (Target) Loading Rate	Final LA	Current Loading Rates	Current Load	% Red.
	Final Hay/Past. LA	509.00	372.70	189703.47	511.94	260580.00	27%
	Final Cropland LA	336.10	3598.39	1209419.67	4942.81	1661280.00	27%
	Developed	3034.40	46.89	142295.80	64.41	195460.00	27%
	Disturbed	770.90	11974.09	9230823.13	16447.81	12679620.00	27%
	Streambank	0.00		1920942.44		2638640.12	27%
				12693184.51		17435580.12	27%

Attachment L
Comment and Response

EPA Region III Comments

Comment
The public noticed TMDL Report addressed iron, manganese, aluminum, and acidity (pH) as appropriate. However, although the TMDL Report identifies suspended solids as an impairment, the report does not address suspended solids. As you know, each 1996 listed waterbody must have all 1996 identified impairments addressed in order to fulfill the consent decree requirements. Therefore, please address suspended solids in the final TMDL Report.

Response:
The final TMDL report for Solomon Creek addresses suspended solids causing impairment in the Solomon Creek Watershed.